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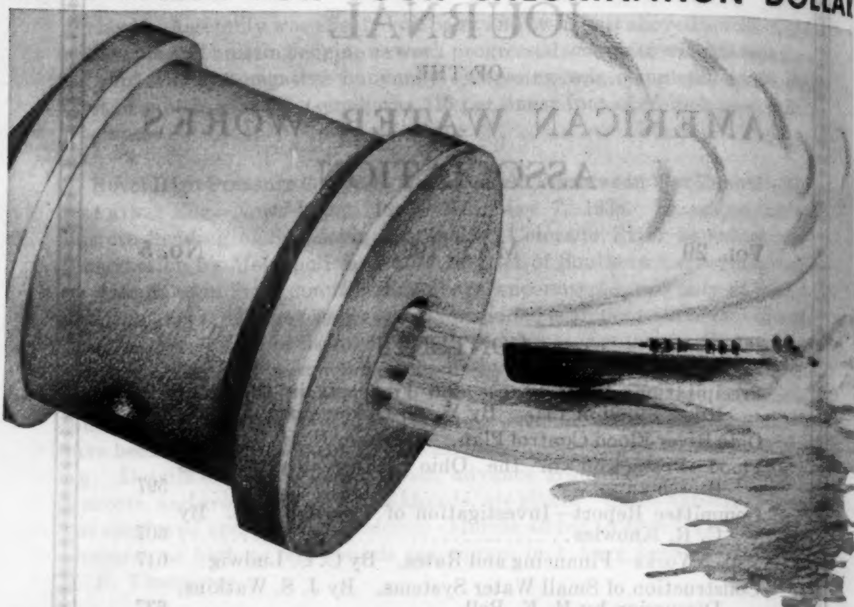

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Vol. 29 MAY, 1937 No. 5

PRECIPITATION, RIVER STAGES AND FORECASTS IN THE OHIO RIVER FLOOD OF 1937*

By W. C. Devereaux

(*Senior Meteorologist, U. S. Weather Bureau, Cincinnati, Ohio*)

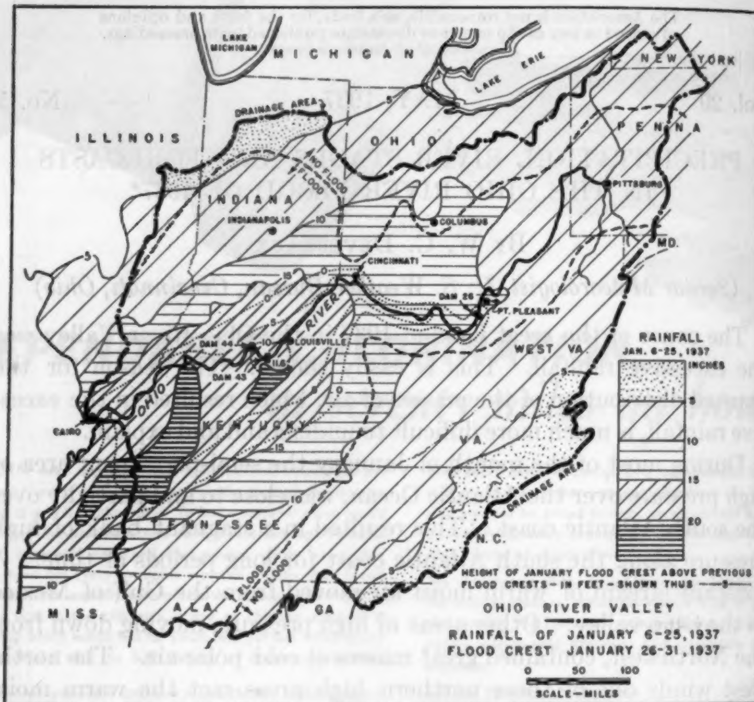
The cause of the great flood of 1937 in the Ohio River Valley was the excessive rainfall. This is easily shown. The reason for the unusual distribution of the masses of air, which resulted in the excessive rainfall, is much more difficult to understand and explain.

During most of the month of January the semi-permanent area of high pressure over the Atlantic Ocean, was close to and partially over the south Atlantic coast. This resulted in a stagnant bank of high pressure along the south Atlantic coast for long periods of time. A constant stream of warm moist air moved from the Gulf of Mexico to the Ohio valley. Other areas of high pressure, moving down from the Northwest, contained great masses of cold polar air. The northwest winds out of these northern high areas met the warm moist winds from the south over the lower Ohio valley. The line of air mass discontinuity, or trough of low pressure, extended from Arkansas northeastward to Indiana or Ohio. For several days this "line" was over or parallel to the lower stretches of the Ohio river extending from Cairo, Ill., to Cincinnati, Ohio, and beyond.

As the cold heavy air from the northwest moved in and under the warm moist air from the south, the temperature dropped rapidly, and great quantities of moisture were precipitated. Along this line

* Presented before the Indiana Section, March, 1937.

of discontinuity, comparatively small areas of low pressure develop, and move rapidly northeastward. On some of the weather maps during January, as many as three of these depressions were shown on one map. When one of these small low areas passed a certain location, the rain would cease for a short time, but a few hours later it would again become heavy and excessive. It is between these two opposite masses of air where the famous "squeeze" occurred that gave the great rainfalls.



The rainfall was moderately heavy in the Ohio valley in December and early in January, but for the period from Jan. 6th to 25th the rainfall was really excessive. During this 20-day period the rainfall amounted to over 20 inches in portions of western Kentucky and to between 15 and 20 inches from Cincinnati southwestward across southern Indiana, the western half of Kentucky and northwestern Tennessee. Over most of the region from Indianapolis to central Tennessee, and as far up the Ohio valley as Zanesville, Ohio, the amounts ranged from 10 to 20 inches. In contrast to these excessive rainfalls over the middle and lower portions of the Valley, the precipi-

tation for the same period was less than five inches in northern Indiana and along the southeastern edge of the Valley in Kentucky and Tennessee. The distribution of the precipitation was most remarkable.

THE CHARACTER OF THE FLOOD

There are many unusual features of the flood in the Ohio river, but none are more interesting than the method by which the flood started at the mouth of the river and progressed upstream to the headwaters. This was brought about by the distribution and amount of rainfall. In table 1 are shown the stages for the full length of the river on three outstanding dates together with comparative data for other years.

On January 10th the Ohio river first reached flood stage, and this was at Cairo at the mouth of the river. On that day the river was from one-half to two-thirds full of water from Pittsburgh to Louisville and nearly full in the Evansville district. The rains continued heavy and on January 18th the river reached flood stage in the Cincinnati district and as far up as Point Pleasant, West Virginia. During eight days the flood had progressed up the Ohio River 716 miles.

On January 24th, already known as Black Sunday, the Ohio river was in flood its entire length, and the stages were above all previous records from Portsmouth, Ohio, to Cairo, Illinois. The excessive rains ceased the following day and the river reached crest at most stations in a day or two except in the lower portion where the crest occurred on February 2nd.

The crest stages in the Ohio river were the highest ever reached from Point Pleasant, W. Va., to Cairo, Ill. The excess above previous records increased from 1.6 feet at Dam No. 26, just below Point Pleasant, to as much as 11.6 feet at Dam No. 43, below Louisville, and then gradually decreased to 3.2 feet at Cairo. At Cincinnati the crest stage was 80.0 feet (79.99 to be exact) and the excess above the high stage in 1884 was 8.89 feet. As measured both by the highest gage readings and the greatest excess above previous records, the flood was most severe from just below the Falls at Louisville to Dam No. 44. In that 60-mile stretch of the river the highest stages were between 81 and 86 feet, which were from 10 to 11 feet or more above all previous records.

All the tributaries which enter the Ohio below Cincinnati were in superflood. The larger tributaries were in extreme flood in the lower

TABLE 1

Stages of the Ohio River taken between 7 and 8 a.m. on three outstanding dates during the flood of 1937, with comparative data

January 10th, first flood stage in the Ohio River at Cairo, Ill. January 18th, first flood stages in the Cincinnati District. January 24th, (Black Sunday) above previous records, Portsmouth to Cairo.

STATION	FLOOD STAGE	JANUARY 10	JANUARY 18	JANUARY 24	CREST AND DATE		PREVIOUS HIGHEST AND YEAR		CREST ABOVE Flood stage	CREST ABOVE Previous highest
Pittsburgh	25	19.0	22.0	29.2	34.5	Jan. 26	46.0	1936	9.5	
Dam #7,	30	20.1	24.7	38.1	44.4	Jan. 26			14.4	
Dam #10,	30	18.7	25.0	41.0	45.1	Jan. 26			15.1	
Dam #12,	36	19.8	28.2	45.0	48.7	Jan. 26	55.5	1936	12.7	
Dam #14,	37	20.5	31.5	48.0	49.4	Jan. 26			12.4	
Dam #16,	38	19.0	32.1	48.0			58.9	1913		
Parkersburg	36	18.0	35.0	50.6	55.4	Jan. 26	58.9	1913	19.4	
Dam #22,	44	19.9	40.9	56.9	60.48	Jan. 27	65.5	1913	16.48	
Pt. Pleasant	40	21.4	41.6	56.6	62.7	Jan. 27	62.8	1913	22.7	
Dam #26,	50	26.4	48.0	64.0	70.3	Jan. 27	68.7	1913	20.3	1.6
Dam #28,	50	23.4	46.6	63.3	69.3	Jan. 27	65.3	1913	19.3	4.0
Dam #29,	51	26.8	50.3	67.6	73.61	Jan. 27	70.0	1913	22.61	3.61
Dam #30,	52	27.8	50.6	68.8	74.69	Jan. 27	69.8	1913	22.69	4.89
Portsmouth	50	28.0	50.0	68.8	74.23	Jan. 27	67.9	1913	24.23	6.33
Dam #32,	53	29.4	49.5	70.2	75.5	Jan. 27	69.0	1913	22.5	6.5
Dam #33,	50	30.8	49.6	69.5	75.34	Jan. 27	68.4	1913	25.34	6.94
Dam #34,	49	29.9	47.3	67.7	73.75	Jan. 26	65.0	1913	24.75	8.75
Dam #35,	48	30.8	47.7	68.8	75.12	Jan. 26	66.2	1884	27.12	8.92
Dam #36,	52	35.1	51.9	72.9	79.75	Jan. 26	70.2	1884	27.75	9.55
Cincinnati	52	36.6	52.4	73.4	79.99	Jan. 26	71.1	1884	27.99	8.89
Dam #37,	50	36.9	52.7	72.9	78.82	Jan. 26	69.0	1884	28.82	9.82
Dam #38,	51	37.1	52.5	72.0	78.6	Jan. 26	69.2	1884	27.6	9.4
Dam #39,	48	34.2	47.9	67.2	73.51	Jan. 26	64.1	1913	25.51	9.41
Louisville, Upper	28	17.0	30.8	51.5	57.15	Jan. 27	46.7	1884	29.15	10.45
Louisville, Lower	57	42.7	59.8	81.5	87.37	Jan. 27	76.3	1884	30.37	11.07
Dam #43,	57	42.2	59.1		86.1	Jan. 27	74.5	1884	29.1	11.6
Dam #44,	53	42.5	59.3		84.2	Jan. 27	73.5	1884	31.2	10.7
Dam #45,	47	38.8	51.8	65.1	69.4	Jan. 28	60.9	1884	22.4	8.5
Dam #46,	41	33.9	43.1	55.1	54.8	Jan. 29	49.3	1913	13.8	5.5
Dam #47,	38	37.6	45.2	52.0	56.7	Jan. 31	50.7	1913	18.7	6.0
Evansville	35	34.8	42.8	49.4	53.75	Jan. 31	48.4	1913	18.75	5.35
Dam #48,	38		44.8	52.8	58.8	Feb. 1	52.2	1913	20.8	6.6
Dam #49,	37		44.2		64.8	Feb. 1	57.6	1913	27.8	7.2
Paducah	39				60.8	Feb. 2	54.3	1913	21.8	6.5
Cairo	40	40.8	47.8	56.8	59.6	Feb. 2	56.4	1927	19.6	3.2

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portion while flood stages were not reached in the upper portion. This is well illustrated in the Kentucky river. For the first 130 miles up this river the stages were from three to seven or more feet higher than ever before recorded, for the next 60 miles the river was in moderate flood, but for the remaining 230 miles of the Kentucky and North Fork rivers flood stages were not reached. A similar condition existed in the Cumberland and Wabash rivers.

The relation between rainfall and river stages was remarkably close in this flood. Where the rainfall averaged 20 inches in three weeks time, the river stages were the highest. In all the area where the rainfall was 15 inches or more, the river stages were the highest of record, and in the region where the rainfall exceeded 10 inches the rivers were in flood. These conditions applied to the tributaries as well as the main stream. Very little flooding occurred where the rainfall was less than 10 inches.

FORECASTING RIVER STAGES

The forecasting of river stages where the flood works upstream is a most difficult problem. We are not quite expert enough to tell the exact amount of rain that will fall in each storm. The full effect on the river stage can be determined only after the rainfall has been measured. The excessive rains ended at Cincinnati near midnight January 24th–25th. The local tributaries stopped rising a few hours later and the Ohio reached a crest within 24 hours. The best forecast that could be made under the circumstances was to keep the probable crest four feet above the water surface each hour while the river was rising rapidly and the rain falling heavily, and then gradually decreasing the clearance as the rate of rise decreased.

The forecasting of the river stages is only a comparatively small part of the service furnished by the Weather Bureau. The hourly collection of weather and river information and the prompt transmission of this information to the general public is the really big phase of the service. Cincinnati was fortunate in this flood in having only 10 percent of its area covered with water, and being able to maintain its lines of communication. This city was for several days the principal center for collecting and distributing river information for a large part of the Ohio valley. With five regular broadcasting stations, five special short wave stations, the newspapers, press associations, telephone and telegraph companies and other agencies giving out information day and night, the whole country was kept well informed of conditions in the Great Flood.

It would have been very fine, theoretically and possibly otherwise, to have been able to make a crest forecast of an 80 foot river stage for Cincinnati two weeks in advance. After many years experience in the work, I doubt that much if any preparation would have been made for such a flood. The water has to be in sight before property will be moved. The U. S. Engineers made estimates several years ago that a stage of 82 feet was possible for Cincinnati by using the greatest rainfall up to that time. If certain changes in the atmospheric structure had been delayed a few days after January 24th, the 82 feet and possibly higher would have resulted. By combining the 1937 rainfall with other heavy precipitation, it is now estimated that a stage three or four feet higher may occur sometime in the distant future.

In discussing the flood of 1937 there are three questions that excite the most interest, viz.:

1st. What was the cause of the flood?

2nd. How great was the flood?

3rd. What can be done about it?

I have attempted to answer the first two questions briefly. With your permission I will make a few personal observations on the last question as this subject is more directly under other Federal and State agencies than the Weather Bureau.

FLOOD CONTROL

We cannot control the weather nor the amount of rain that falls, and I doubt if we can control the amount of water that passes down the Ohio river in a great flood. The volume of water is so great that it is hard to grasp its full significance. At the crest of the flood, the volume of the water passing each five seconds would have supplied Cincinnati with water for domestic uses for 24 hours. If all of the water that passed above the flood stage of 52 feet had been stored, it would have required 90 dams the size of Wilson Dam, 12 or 13 the size of Norris Dam, and 6 or 7 the size of Boulder Dam. This gives you some idea of the water in a great flood.

While man cannot control the weather, or the rainfall, or the river in its total discharge, still he can control the detrimental effects of these elements. Artificial heat can be supplied to offset the cold, shelter can be provided against the excessive rains, and some of the water can be held back in the tributaries and the river channels improved.

The first point of attack in the control of the flood heights is on the

land where the rain falls. It has been shown that by the proper treatment of the soil and reforestation and other methods, a considerable amount of the run-off can be retained at the headwaters. In the tributaries and small streams, the water can be further retained by storage dams and ponds. However, when the water reaches a larger river like the Ohio, it becomes impracticable to retard the flow. The best method here is to open up the river as much as possible and to protect property by walls and dikes.

Of the great public utilities that need protection from floods, the water supply is the greatest of them all. The "darkest" time in the Great Flood in Cincinnati was when the water was cut off. Man cannot live long without water.

In protecting this vital necessity of life from future floods, it seems advisable to expect another flood as great or even greater in the future. Of course we all hope that another great flood will not come, but "hope" does not keep the water away. In protecting water systems from high water, there comes a time when it is more practicable to provide auxiliary supplies. Each system requires a different treatment.

In conclusion I quote from an Address by Willis Ray Gregg, Chief, Weather Bureau, before the Society of American Military Engineers, Monday, February 15, 1937.

"A few words may be of interest as to plans and hopes for the future. River and flood forecasting has in the past been in considerable part empirical in character. This was unavoidable during the pioneer stage. However, it is now possible and steps are being taken to put forecasting on a more rational basis. In these efforts special investigations are being made of the relation between rainfall and run-off, and therefore between rainfall and the occurrence of floods. In order to bring these improvements about, reorganization of the river and flood service of the Weather Bureau is proceeding along the following lines as rapidly as funds permit:

"(1) The establishment of more and better placed rainfall stations, especially in head-water regions.

"(2) The installation of an adequate network of recording rain gages to enable the forecaster to know the intensity of the rainfall. At present most of the rain gages used in flood work are of the eye-reading, 8-inch type.

"(3) Surveys of the amount and condition of snow in the mountains, from which little information concerning snow is

now available. Reliable and prompt rainfall reports are not sufficient when the mountain regions hold a great amount of water in the form of snow, which is likely to be released by the rain.

"(4) Arrangements for a more reliable transmission of rainfall and river stage reports from the substations to the district centers. In the eastern floods of March 1936 the failure of wire communication was almost entirely responsible for any lack of timeliness and accuracy in the warnings issued. One suggestion is to establish radio stations in the flood producing regions and have them manned by Weather Bureau employees to transmit reports promptly under all conditions in order to avoid the possibility of a complete lack of information when wire communication breaks down. Another plan is to enlist the coöperation of amateur radio operators. Both of these suggestions are being studied with a view to determining some way in which the necessary data can be secured in all cases.

"(5) Perhaps the most important feature of the reorganization is the division of the country into eight districts, each to be under the supervision of a hydrologic engineer, with a suitable staff of trained men. Under this plan each district center will be responsible for placing and supervising the operation of all substations, developing and putting into effect the transmission of reports to the forecasting centers, coördinating all phases of the work, including coöperation with other organizations, and developing formulas for forecasting. Through close coöperation with the Geological Survey discharge data are becoming available for all of the rivers of the country, and these data can be used to great advantage in combination with Weather Bureau data in the development of formulas that will bring about considerable refinement in the river stage and flood forecasts.

"A beginning has been made in carrying out this general plan, two such district centers having been established at Davenport and Kansas City. It marks a definite departure from the practice of the past in that the men engaged in the work will be specialists therein, with no other duties. It is gratifying to be able to state that in those two districts the change has been received with enthusiasm by Army engineers engaged in flood control and other allied projects and by the representatives of all other agencies that have a part in this work."

OHIO RIVER FLOOD CONTROL PLAN*

By Major H. H. Pohl, Corps of Engineers, U. S. Army
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(Cincinnati, Ohio)

Since the earliest times of which we have record, the areas contiguous to the rivers and streams of the central portion of the United States have been subjected to floods resulting in the destruction of property and loss of life. For the Ohio River Valley, the flood of 1937 was merely the highest and most disastrous of the series. It has caused a lively and vital interest in the whole subject of floods and their control. It seems probable that the disaster will result in measures being taken in the near future to prevent a recurrence.

The severe flood of 1927 on the Mississippi River resulted in the passage of the Flood Control Act of 1928 adopting the "Jadwin" plan of flood control for the Mississippi Valley. This plan, named after General Jadwin, then Chief of Engineers, was evolved by the Army Engineers and has been prosecuted by them since it was authorized. While not yet completed, this project enabled the greatest known flood the Ohio River has had to pass through the Mississippi Valley to the Gulf of Mexico without damage to that valley. It may be that the people of the Ohio Valley are now learning what the inhabitants of the Mississippi Valley learned in 1927, that is, that the best way to secure flood protection is to have a good flood.

EARLY FLOODS

The first authentic record of an Ohio River flood appears in a letter written by a British officer who was Commandant at Fort Pitt, which stood on the site of the present city of Pittsburgh. He describes the floods of 1762 and 1763 in that vicinity. The flood of 1763 reached a stage of approximately 40 feet on the present Pittsburgh gage. There is also a legendary report of a flood in the vicinity of Cincinnati about 1773 which approximated 75 to 76 feet on the present gage as compared with the stage of 80 feet reached this

* Presented before the Indiana Section, March, 1937.

year. If this flood actually occurred, it was of a magnitude comparable to the flood just experienced and may possibly have been somewhat greater, in spite of the difference in stages reached. The flood of 1773 occurred when the valley was in its primitive state before man had encroached upon the flood plain by building artificial obstructions. More recent floods within the memory of men now living occurred in 1883, 1884, 1907, and 1913. Since 1832 the river has exceeded a stage of 60 feet on the Cincinnati gage some 14 times. At Louisville it has exceeded a stage of 35 feet on the upper gage 16 times within the same period.

The history of floods on the lower Mississippi River is similar, although the records go back much farther than on the Ohio. The first Mississippi flood of record is recorded as witnessed by De Soto in 1543. He observed it from about the site of the present city of Helena, Arkansas. It was reported to have lasted about 80 days, and, allowing for the possibility that the story improved with time, it was probably a flood of some magnitude. In 1717 the city of New Orleans was founded and with that year the authentic flood records of the Mississippi begin, although they do not become continuous until 1799. From that year until the present, floods have occurred on the lower Mississippi with an average frequency of one in from two to three years. This historical information is cited to show that floods are really an old story on the rivers of the middle west. It is practically certain that they will continue to occur, and, unless preventive measures are taken, they will continue to exact their toll of property and lives. There is every reason to believe that a flood of a size comparable to the recent one occurred some time in the past. The valley of the Ohio has been exploited and the river bed has been encroached upon, but these actions of men cannot be said to have caused the floods.

Although no one can say when it will occur, it is extremely probable that a flood of the size of the recent one will occur again in the future. Precautionary measures taken in advance of the recent flood in most cases did not provide for the heights to which the water rose. However, the flood did not come entirely unpredicted. The flood control studies made by the Engineer Department about 1933 indicated the possibility of a flood of this magnitude. The studies indicated the possibility of a stage of 83 feet at Cincinnati, and the water came to 80 feet.

Naturally there has been considerable discussion of the causes of

the recent flood. You have been told the meteorological conditions which led up to the unprecedented rise in the river. In brief, the disaster was the result of a tremendous amount of rain falling upon a ground which had already been saturated by previous rains so that run-off became practically 100 per cent.

METHODS OF FLOOD CONTROL

Obviously we cannot control the weather and prevent floods. The problem of flood control becomes, therefore, one of keeping the dangerous waters from damaging our communities. There are several methods by which waters are controlled to prevent this damage. One method is that of diversion or channel relocation, that is, guiding the excess flood flow from the channels where it would wreak havoc into artificial or partly artificial flood channels through which it may be carried to the sea with little or no damage to the natural valley of the stream. Any one who has witnessed the recent flood knows how enormous such diversion must be to be of any value in the Ohio River Valley. The topography of the valley allows no chance for such a method. It may therefore be discarded as impractical.

A second method somewhat similar in idea to diversion is that of channel improvement. Channel improvement seeks to improve the hydraulic characteristics of the natural channel so that it can carry flood discharges without permitting the water to rise to dangerous heights. There is a possibility that this method might be used to some advantage in restricted reaches of the lower river. However, its use would be very limited and the method cannot be taken as a basic method for a comprehensive plan covering the entire valley. The work of widening, straightening, and deepening the channel throughout its length to accommodate a flood similar to 1937 without dangerous stages is obviously impractical.

RESERVOIRS FOR FLOOD CONTROL

This brings us to the consideration of reservoirs as a means of flood control. This method is not new in the Ohio Valley. In fact, it is learned that such a method was proposed as early as 1852 by a Mr. Charles Ellet, who was then engaged in a study of the Lower Mississippi. Ellet's idea was not the protection of the Ohio valley, as he was preoccupied with the lower Mississippi. However, he probably recognized that some incidental benefit might be expected

in this valley. It is interesting to note that even at that early date the plans for reservoirs contemplated their construction on tributary streams only. Mr. Ellet apparently had no idea of advocating the construction of a dam across the Ohio river itself.

Reservoirs were first seriously advanced as a means of flood control in this valley after the disastrous flood in the upper river in 1907. This flood caused great damage at Pittsburgh. A Pittsburgh Flood Commission was then organized and it made a comprehensive study culminating in a proposal that reservoirs be constructed for the protection of that city.

The disastrous flood in the Miami valley in 1913 resulted in the formation of the Miami Conservancy District which actually undertook and finished the construction of a reservoir system of flood control in that valley. The history of that project and the manner in which it functioned in the recent flood is well described in an article in the March, 27 (1937) issue of the Saturday Evening Post. Another Conservancy District has been formed in Ohio in the last few years and is now nearing completion under direction of the Army Engineers. This is the Muskingum project. Although only 3 of the 14 reservoirs have been completed, it is estimated that, in its unfinished state, the project lowered flood heights at Zanesville by about 4 feet in the recent flood. You thus see that reservoirs are not only a tried and proven method of flood control under certain conditions, but also that they are now in use in this valley.

ARMY ENGINEERS PLAN

The flood control plan, which is ordinarily called the Army Engineers' Plan, has been prepared over the last 10 years and contemplates the construction of some 88 reservoirs located on tributary streams throughout the Ohio Valley. These reservoirs will afford a large measure of protection on the streams on which they are built. Their coördinated operation will cause appreciable reductions in flood stages along the banks of the main stream. It is calculated that these reductions at Pittsburgh will amount to from 9 to 13 feet, depending upon the size of the flood. At Cincinnati they will amount to from 5 to 8 feet, and at Louisville from 2 to 3 feet. These calculations are conservative. Under favorable conditions, when the reservoirs can be operated with the greatest efficiency, greater flood stage reductions will be effected even for major floods. I particularly wish to emphasize the fact that these reservoirs will be

effective for tributary floods as well as for main river floods. This is one important basis for their justification. However, it is obvious that they are not the complete answer to the flood problem of the Ohio river. Additional protection is necessary. Local protection for riverside communities which will be damaged by floods despite the operations of the reservoirs must be provided.

None of the reservoirs contemplated in the Army Engineers' plan would be constructed upon the Ohio river itself. However, the possibilities of main stream reservoirs have not been neglected and consideration has been given to such reservoirs. In fact, a proposal to construct one such reservoir on the lower river is fully discussed in the report. The site is about 3 miles above the town of Golconda, Illinois, and 78 miles above the mouth of the river. It is possible that a reservoir might be constructed at this location to provide a net storage capacity of about 6,400,000 acre-feet, and which would reduce stages at Cairo by about 2 to 3 feet. However, the construction of such a reservoir would be enormously expensive and would cause a flooding of valuable farm lands as well as towns above the site. Such a reservoir would add to the protection of lands along the Mississippi river but it is estimated that, for every acre of land protected below the dam, at least one acre of good farming land upstream would be flooded. The backwater from the reservoir would extend as far as Evansville and the water would reach a height there only a few feet below the crest stage of the 1937 flood. Therefore, expensive flood protection works would be necessary at that city as a part of the scheme.

Upstream from this site, the valley becomes more thickly populated and more heavily industrialized. Any Ohio river reservoirs would inundate the very areas which we propose to protect. Thus the conclusion reached is that main stream reservoirs for flood protection are entirely impractical.

RESERVOIRS NOT COMPLETE PROTECTION

You have noted that the construction of the headwater reservoirs would lower flood crests along the lower river by only several feet. This has been taken into account in the Army Engineers' plan and local protection works are contemplated to supplement the effect of the reservoirs. Levees and flood walls present the solution for this supplementary protection. They have been used as a means of flood protection as long as man has a record of his work. The

first levee to be built on the lower Mississippi was completed in 1727 for the protection of New Orleans, which was then only a small settlement. Levees form the main feature of the "Jadwin" plan for flood control on the lower Mississippi. The Engineer plan for the Ohio river proposes a series of these works to protect local communities, and it is proposed to build these local protection works on the lower river to such heights that they will afford adequate protection against an uncontrolled flood. This will permit their construction without reference to the progress of the reservoir program. A city thus protected will be safe during the period the reservoirs are under construction, and reservoir operation will furnish an additional factor of safety for the communities.

The detailed locations of individual levees and flood walls for particular cities depend upon many things. Foundation conditions must necessarily be considered and rights-of-way must be acquired. It will be necessary to make changes in street and highway systems. Sewers must be modified to prevent flood waters backing up into them and flooding the protected areas. Provision must be made for the disposal of sewage and surface drainage during floods.

LOCAL COOPERATION NECESSARY

Consideration must also be given to the desires of the people of the community in planning these works. This necessitates close coöperation between the constructing agency and the municipalities concerned. The location of the walls necessarily brings up the question of evacuating certain areas instead of protecting them. This question must be decided in each individual case and the decision rests upon the following considerations: First, is it possible to protect the area? Second, is it economically feasible to do so? Third, does the municipality want protection? If, from the engineering standpoint, protection is not possible, there is only one answer. The question of economic feasibility opens up an almost endless range of discussion. Municipal planning must be considered as well as other features. This phase of the problem must be solved by the municipalities concerned. It may be stated that the Army Engineers' plan does not contemplate forcing any plan for local protection upon a community which does not desire it. Within the limits of sound engineering, hydraulics, and economics, it is our desire to give interested cities adequate protection of a type which is desired.

Your principal interest is to learn exactly what the Engineer Department has done and contemplates doing on the matter of this Ohio River flood control. In the article on the Miami Conservancy District, previously mentioned, there is a quotation from Colonel E. A. Deeds, who was one of the leaders in forming the Dayton Conservancy District and completing its plan. Colonel Deeds warns against undue haste in prosecuting a plan. He speaks of an understanding that there is filed away in some pigeon hole a plan which can be drawn out and put into effect tomorrow, if the money is appropriated. I wish to disclaim any idea that the Engineer Department has such a marvelous plan. However, the Department has been working on flood control for years and has accomplished certain definite things.

The Flood Control Act of 1927 authorized the Corps of Engineers to proceed with a comprehensive study of all the streams of the country. All the information and data compiled by the Engineer Department over its 120 years of service were reviewed, additional surveys were made, and reports submitted to Congress on all streams. The report for the Ohio river was submitted to Congress in 1935 and was published as House Document 306, 74th Congress, First Session. The Engineer plan is the result of these studies and reports. The Flood Control Act of 1936 authorized the construction of certain reservoirs which are a part of the formulated plan, but did not appropriate money for their construction. While detailed plans have not been made for the greater number of the reservoirs nor for the local protection works, detailed plans have been made for as many of the reservoirs as possible with the funds made available. Some of the reservoirs, in fact, have been constructed and others are under construction. Such are the Tygart reservoir, for which a P.W.A. grant was made several years ago, and the 14 reservoirs of the Muskingum system, partly completed.

To prosecute any engineering project, certain things are necessary. There must be preliminary information and data upon which to make plans. Plans must be drawn up for the work. An organization must be available to carry out the project, and money must be available. For the flood control of the Ohio river, the Engineer Department has the necessary data, compiled over a period of some years. From these data a comprehensive plan has been evolved which is not a hastily conceived idea, but a project based upon detailed and thorough studies. The Department has an active and

able engineering organization which fits exactly into the watershed of the Ohio Basin. This organization is the Ohio River Division, under Colonel R. G. Powell, which has been functioning on the Ohio river for some years. Only money is lacking. Should appropriations be made available, the Department is prepared to proceed with the actual construction of those reservoirs for which plans have been completed and to continue the detailed design of the remainder of the project.

FLOOD PROTECTION IN THE OHIO VALLEY*

By Charles Brossmann
(*Consulting Engineer, Indianapolis, Indiana*)

What are we to do about the Ohio Valley, and what shall the state of Indiana and other states do? When one looks at an entire valley such as the Ohio, and the destructive forces and magnitude of this river are realized, it seems almost impossible to believe that anything can be done. In fact when one says that things should be done, there are instantly a number of people who claim it is not possible.

However, the Ohio Valley represents a long distance. For almost a thousand miles the river winds from Pittsburgh to Cairo, gathering in volume and force and water all along from many large and small tributary streams. There are two dozen large size streams between Pittsburgh and Cairo. These are fed by many small creeks and tributaries, and in addition to this, are the many small creeks and tributaries that flow directly into the Ohio, between these streams of larger size. The greatest of these is the Tennessee River, already partially controlled by Mussel Shoals, Wheeler and Norris dams. There is the Great Miami—a smaller river compared to the others, but under control. Our own Wabash River on a rampage is nothing to be sneezed at, and the gathering of the waters of all these tributaries into the Ohio during the recent flood, represents water to the amount of almost two million cubic feet per second, which to the lay mind may not mean anything but a figure, but it means the passing of as much water in two seconds, as is used in the entire City of Indianapolis in twenty-four hours. It means in one minute more water than the entire City of New York and its Boroughs, use in one day. It means almost forty thousand acres, or about sixty square miles of area filled with water 100 feet deep, in one day.

This is so much water that it is almost impossible to comprehend it. Fortunately these inundations are very far apart, and only come, perhaps, once in a hundred years. But, we ask, "What's to do about it?" and "Can these cities be made safe, that have taken the brunt of this overflow of Nature?"

* Presented before the Indiana Section, March, 1937.

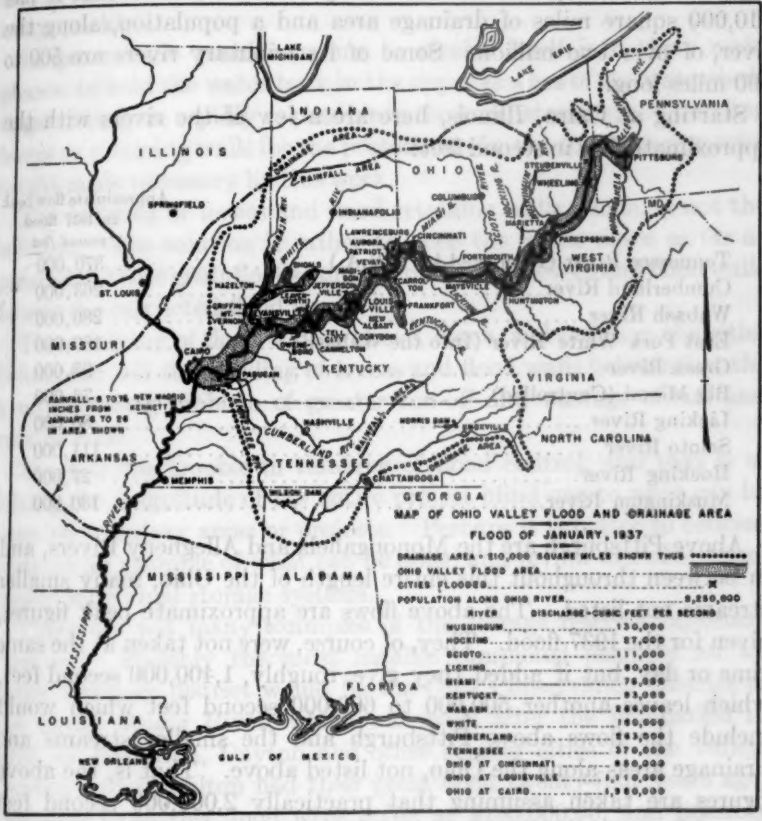
That is a pretty difficult question, that no one cares to answer off hand. However, there is much that can be done, and so many other things that go along directly with the floods, and their contributing causes, that these many matters should be given consideration. For the past twenty-five years many things have been preached in relation to drainage, soil erosion, reforestation and the building of natural water reservoirs, the necessity of stopping certain ill advised drainage projects that would do more harm than good. Selfishness and the desire to enrich at others' expense, in the drainage of certain lands; farming over certain areas with improper crops (the great example of which is the great dust bowl); all of these things are contributing factors that upset the balance of Nature in conservation, and the control of our natural resources.

There is no necessity for me to tell you that over-drainage of farms is bad, when I tell you that hundreds of thousands of miles of drainage tile, and thousands of miles of ditches are in the State of Indiana alone. How much more is in the other states? This is not a question that farm drainage is not right. It is a question of improper application or of overdoing it. It is not necessary for me to stand here and tell you that soil erosion is the rule and not the exception, in most of the counties in this state.

Doctor Stephen S. Visher, Professor of Geography, at Indiana University, has made the statement that if the rate of soil erosion which has prevailed in Indiana, is allowed to continue, many of our sloping lands will soon be practically ruined. In fact, thousands of acres in southern Indiana, have been abandoned because little top soil remained. Federal land experts, about a month ago, made the statement the last flood had washed away 300,000,000 tons of fertile top soil from 127,000,000 acres in the Ohio water shed. These experts said the flooded areas formerly were covered with 98 percent forest as against 37 percent now, and that about 65 percent of the entire area was eroded; that field tests during the Ohio flood, demonstrated that four times more water runs off corn fields than from grass or woodland.

Is it necessary to call attention to the drainage projects such as the Kankakee marshes; or the present attempted Wabash drainage project, which has been in the courts for ten years, and on which Governor Townsend recently signed a bill to hold up the Court order sustaining this drainage? Is it necessary to point out the attempted drainage of the lakes in Noble and Steuben Counties, a number of

years back, which was frustrated by the State Department of Conservation? All of these things vitally affect floods, and natural resources, and the sloughing away of our land and carrying it to sea. These floods of great magnitude are enough to call for protective measures, even on soil erosion alone, and when we consider the effect they have on floods, how much more important it is.



During the recent flood, in Indiana alone, there were nineteen to twenty counties affected, and at least 15,000 families needing relief. We are not in this thing alone. We are only one of many states affected in the Ohio Basin. Kentucky, Indiana, Tennessee, Ohio, West Virginia, Pennsylvania,—all of these states are contributory to the Ohio Valley, and the problem is to bring together and reconcile the various thoughts and possibilities on flood control.

There may be a difference of opinion, but it is questionable whether the difference is fundamental. All of the primary features governing drainage, soil erosion and building of reservoirs are fundamental and are of the utmost importance. The dredging and deepening of channels are problems of the main tributaries, as are the building of levees and retaining walls.

Glance at a map of the Ohio Valley area. Consider that it has 210,000 square miles of drainage area and a population, along the river, of over two million. Some of its tributary rivers are 500 to 600 miles long.

Starting at Cairo, Illinois, here are a few of the rivers with the approximate flow in second feet:

	Approximate flow peak in 1937 flood *second feet*
Tennessee River (Improved by T.V.A.)	370,000
Cumberland River	263,000
Wabash River	286,000
East Fork White River (Into the Wabash)	180,000
Green River	93,000
Big Miami (Controlled)	76,000
Licking River	80,000
Scioto River	111,000
Hocking River	27,000
Muskingum River	130,000

Above Pittsburgh are the Monongahela and Allegheny Rivers, and in between throughout this entire length of the Ohio, many smaller streams not listed. The above flows are approximate peak figures, given for the 1937 flood. They, of course, were not taken at the same time or day, but if added they give, roughly, 1,400,000 second feet, which leaves another 500,000 to 600,000 second feet which would include the flows above Pittsburgh and the smaller streams and drainage areas along the Ohio, not listed above. That is, the above figures are taken assuming that practically 2,000,000 second feet passed from the Ohio into the Mississippi. These figures are simply an index of the contributing flows into the Ohio, and of course, the Ohio is the stream which caused the most damage and distress in this region. Analyzing this, it may be seen that one phase of the problem resolves itself into the control of each of these individual sections. The Great Miami River is already under successful control, with very good evidence as to what has been accomplished.

This individual problem of each section, then, resolves itself into

all the various factors mentioned, comprising soil erosion, farm drainage, proper type of farming; crops, including reforestation of certain areas and strips; the analysis of drainage problems; and the building of small dams and larger impounding reservoirs. This becomes the one problem of holding the water back. The second problem becomes that of widening and straightening the streams, where necessary in the lower reaches of the flood area, so this water may be gotten away quickly.

In general the problem seems to resolve itself into three main phases: to hold the water back in the upper reaches of the watershed; to get it away as rapidly as possible in the lower streams; and building levees or retaining walls for the protection of cities to the compromise height made necessary by this work.

The building of levees and flood retaining walls, alone, is not the solution. The solution is rather to keep the water down as far as possible in these great floods, and the building of levees and flood walls to suit the restricted flood levels.

The retaining of flood waters above, alone, will not save the cities below, nor will the building of levees and flood walls below offset the ever increasing problem of greater run-off and wastage of soil and ruin of land.

There is one trouble in thinking of flood control, and that is of letting the magnitude of the entire project blind one to what can be done on tributary areas or projects. Perhaps it is better to concentrate on an example of what can be done, and review one of the successful individual storage systems.

There are not many examples of the storage reservoir systems, "per se." Possibly the most notable completed example for an entire drainage district would be the Ohio Conservancy District of the Great Miami River, which was built after the inundation in 1913, of Hamilton, Dayton and other smaller cities of the valley. Dayton and Hamilton had their great flood twenty-four years ago. Damages from this flood were given at $100,000.00, and possibly 400 lives were lost. This was the great flood of March, 1913, and up to our recent 1937 flood, the Dayton flood was outstanding as a great catastrophe of this kind. However, this district did not sit idly by. They realized something had to be done. Construction was started in 1918 and completed four years later. The cost of this was $32,000,000. Careful engineering studies were made. Five great dams were constructed, the highest being Hoffman Dam, 110

feet high, and almost 1000 feet long. The Miami channel was improved, and the engineers provided against a flood of even greater magnitude than that of 1913. In fact, almost half again as great, and twenty percent more than the estimate of the greatest flood that could occur, after making studies of the drainage area, and rainfall under the worst conditions. The Great Miami Valley, of course, is not as large as many others, the drainage area being possibly 3500 to 4000 square miles, yet how well Dayton and the other cities and inhabitants in this district have succeeded, is shown by this last flood. The people of this valley arose to the occasion and did not wait for a repetition. The flood period in 1937 in this valley from January 13 to 24, followed between 9 and 9½ inches of rainfall, and the river stage at Hamilton, which is down at the southern end of the district, rose to between 16 and 17 feet, which is the greatest height that has occurred since the protection works were completed. The runoff of rainfall for this area was close to 70 percent. This district, therefore, has had its greatest test since the 1913 flood, and yet the impounding reservoirs are said to have been filled only to fifteen percent of their capacity, and even with this large amount of rainfall, no damage occurred in this district. There are between 300,000 and 400,000 persons living in this valley, and I doubt if there are now any regrets over the assessments, and the money spent for this improvement. The City of Dayton, alone, has a population of over 200,000 people. Hamilton, another great city and many other smaller towns are in this valley, none of which were affected in this last heavy rainfall.

One of the outstanding things of this district is the wonderful manner in which the people of these two great cities and this district arose to the occasion for defending themselves against another water invasion. Here was a case of a city directly in the path of the flood, yet within a short period after the 1913 flood waters had gone their way, meetings were held; millions of dollars were subscribed; engineering work was started; intelligent studies were made; and contracts were let as soon as definite plans were formulated.

While the preliminary work and studies, plans, and the securing of riparian rights took a matter of five years, in 1918 construction work was started and in 1922 it was finished.

This is simply an example of the ability of fine energy, aggressiveness and speed to overcome the almost insurmountable. It shows what may be done, and is the greatest and most outstanding example

in this country for a project of this kind. For certain localities there arises the problem of whether it is wise to continue to build in a path that unquestionably will be swept by great floods. In such cases should property repeatedly be placed in the path of a flood? Or should an attempt be made to build higher walls, or levees to protect the property? Of course, there is no rule. The individual case must be analyzed on its own merits. The question of moving a whole town or small city is a Herculean task. The ties, sentimental, financial and others, are so strong that it would be an impossibility to move some places, and many residents prefer the risk of staying and taking chances.

In some localities, and usually in the very poor sections, it is a more or less expected thing to move out ahead of the flood every year or two, and in some better localities ten or twenty or more years apart. And those who live by commerce or who desire to be on the river, cannot be expected to go back from the water any more than you can keep a sailor from his ship. They simply have to live next to the water. Perhaps it would be just as hard to move these people from the river, as it was to move the Seminole Indians from Florida. The Government, many years ago, tried to do this, spent money and sent troops to move them, but the Seminole Indians are still in Florida. They wanted to stay, and probably the river people want to stay. So in such cases, either they will be protected, if possible, or they will get out when the floods come, and go back on its subsidence. However, this does not settle that question, and when there is no hope for the low areas that are inhabited, and if such are settlements of poor construction, it would seem wiser to move such communities and take advantage of a modern housing system for them. It is not intended to convey the impression that impounding dams and reservoirs are a panacea for all flood evils. Where such schemes are the logical solution, they are, of course, entirely dependent upon topography, and a country with streams flowing through level valleys, not too wide, and with high adjacent banks,—is ideal for this purpose. Primarily, topography must be favorable, and there must be sufficient storage capacity to make the building of any impounding dam worth while. Tributaries must have drainage areas to justify consideration of storage reservoirs. Promising streams must be carefully scrutinized and possible sites selected, and studies and surveys made, in order to determine the possibility of the greatest storage up to economical limits. Consideration must be given, in

many cases, to determining where overflow on such land would cause great damage. There will, of course, be many streams where storage reservoir construction would not be possible,—or at least, too expensive to justify the amount of storage. Furthermore, in many cases the working out of a reservoir system must be made to serve the many purposes of flood control, water supply, sometimes water power, and even navigation in the larger streams. Any surveys made should be continued far enough to give preliminary estimates of reliability. There are so many features to be considered, it is impossible to note all of them in a general discussion of this kind.

However, after everything is considered, the reservoir projects could be boiled down to get the greatest storage capacity per dollar expended. A very rough average cost of dams and appurtenances for impounding purposes may be taken at about $250 per million cubic feet capacity. And the total cost, including land and all other costs could probably be given at most, as to dams or any other, at about $500 per million feet of storage capacity. Necessarily, costs will vary with the topography, the type of country, and the size of the project. Such storage reservoirs are not required to have a capacity equal to the entire flood movement. Rather, they are intended to hold back that portion which is at the danger mark or above. Rainfall is such a variable, and the conditions of runoff are so affected by the seasonal ground conditions, that consideration must be given to the worst conditions.

Ground conditions are important, whether dry, saturated or frozen, or whether snow is on the ground, and this condition together with the temperature, all have an effect on the runoff. So many combinations may arise that almost every great flood will be different in character. Knowing all these varied conditions may occur, it becomes necessary to take care of any combination of precipitation and runoff that may occur. Assumptions must be made that at the start of the rainfall it will take a certain period for the water to arrive at the small tributaries. This time will be governed greatly by the ground condition, whether it is forested, cultivated, or whether there is a badly eroded soil condition; then from the first smaller streams, there will be a lapse of time to flow through and get to the larger streams; then to the creeks, and to the rivers, and such time of travel, must be taken into consideration, and a study made of the slope, character and extent of the basin taking this rainfall, and the length of travel. Then the character of the impounding basins will deter-

mine the question of rise. The relative effectiveness of a reservoir project must be considered and how much total reduction in flood figures will be caused by such a reservoir; also the affect of the time element, or diversity factor, if we may call it such, of when one tributary will start to overflow and its relation to the time of overflow of the others that feed into the main streams that cause the worst damage. Obviously, if all of these reservoirs were to overflow at the same time and reach the large streams at the same time, there would be little gain. The fact that a reservoir will have a low cost for storage capacity, will not make it the least expensive for the purpose, if it does not retain the water at the right time, and deliver it to its main tributary at the right time. All of this must be taken into account.

Therefore, storage dams or reservoirs should not be built promiscuously, but only based on the analysis that they will be effective. The effective capacity is very important, and they must be such that they will reduce the flood peak at the danger points, and such effective capacity will give the relative importance. In any case, it becomes necessary to provide sufficient capacity over the entire storage area to retard the water effectively.

Of course, by hand controlled gates, a reservoir may control more water than its actual storage capacity. That is, the gates may be opened so that drainage is going on while the lower dangerous tributaries are at a lower level, and as the lower tributaries rise, then the upper storage reservoirs may be cut down, or closed, up to the point where they are filled. Some of the floods we have experienced have had more than one peak crest. This was evidenced in the 1937 flood as well as previous floods, and in this case, the upper reservoirs could be filled, or be in process of filling, before the time of the last peak.

Conclusions can only be reached after a collection and systematic study of stream flow data and rainfall, the greatest hindrance being that records over long periods are so often not available, or not sufficiently accurate for the purpose intended.

It may be that for some floods and under certain seasonal weather conditions similar to those of 1937, even with all that might be done, we could not solve the problem for the Ohio Valley. The statement has been made that there are records which point to an inundation as great or even greater than the 1937 flood, and of longer duration. This flood is said to have taken place several hundred years ago, in the Indian times, and there is still the question whether anything can

be done to guard entirely against such catastrophes. What should be done with the Ohio basin is still questionable. Much has been collected in the way of preliminary information, and much more must be had in order to reach any conclusion, and this information should be secured before definite steps are taken. However, it also seems reasonable that if the Miami is a successful solution of its particular district, and if the Pittsburgh studies are conclusive for that particular district, the reservoir system, in general, is at least the major solution of the river tributary systems, and points to the practical way to hold back the tributary waters. If the question of how to keep down the maximum flood heights can be answered, then the question of protection of cities, or the moving of those settlements that cannot be guarded against floods, can be settled.

COMMITTEE REPORT*

INVESTIGATION OF TRANSITE PIPE

INTRODUCTION

Compositions of asbestos and cement have been extensively used for many years for roofing and siding on buildings, for flues and stack, for boiler and furnace casings, for electric bus structures, for laboratory table tops, and for a wide variety of purposes in which corrosion resisting, fire resisting and weather proof construction is required.

The first asbestos cement pipe was manufactured by the Societa Anonima Eternit Pietra Artificiale of Genoa, Italy in 1913, manufacturers of asbestos cement products in other forms since 1906. The development of methods of fabricating the pipe extended over a considerable period of time, and in 1913 complete equipment had been installed and the production of pipe was under way.

The trade-name originally adopted for the use of the pipe in Italy was "Eternit." The trade-name "Italit" was later adopted for pipe exported from Italy. In each country where asbestos cement pipe is manufactured and sold, an identifying trade-name is used, such as "Everite" in Great Britain and "Transite" in the United States and Canada.

The pipe was not used extensively, however, until 1916 when approximately 13,500 lin. ft. of asbestos cement water pipe was placed in service in Italy. In 1927 it was introduced into Spain and in 1929 into France. This was followed by its introduction in Austria, Czechoslovakia, Germany, Hungary, and the United States in 1930; in England and Belgium in 1931 and in Canada and Japan in 1932.

DESCRIPTION

Transite Pipe is composed of asbestos fibre and Portland cement combined under pressure into a dense, homogeneous structure in which a strong bond is effected between the cement and the asbestos

* This committee's function is that of fact-finding and reporting thereon, rather than that of preparing specifications. There will be an open discussion of this report at the Buffalo convention on Monday morning, June 7th, 1937.

TABLE 1

Dimensions and approximate weights of transite pressure pipe

PIPE SIZE, INCHES	CLASS 50				CLASS 100				CLASS 150				CLASS 200			
	Thi k-ness Ins.	Outside Dia. Ins.	Weight, Lb. Per Lin. Ft. Pipe Only	Weight, Lb. Per Lin. Ft. Incl. Coup.	Thick-ness Ins.	Outside Dia. Ins.	Weight, Lb. Per Lin. Ft. Pipe Only	Weight, Lb. Per Lin. Ft. Incl. Coup.	Thick-ness Ins.	Outside Dia. Ins.	Weight, Lb. Per Lin. Ft. Pipe Only	Weight, Lb. Per Lin. Ft. Incl. Coup.	Thick-ness Ins.	Outside Dia. Ins.	Weight, Lb. Per Lin. Ft. Pipe Only	Weight, Lb. Per Lin. Ft. Incl. Coup.
2	.34	2.68	2.25	3.2	.41	2.82	2.8	4.0	.46	2.92	3.22	4.47	.50	3.0	3.56	4.88
2½	.34	3.18	2.75	3.86	.41	3.32	3.39	4.75	.46	3.42	3.87	5.27	.50	3.5	4.26	5.76
3	.36	3.72	3.43	4.7	.44	3.88	4.28	5.8	.49	3.98	4.86	6.43	.53	4.06	5.32	7.01
3½	.36	4.22	3.94	5.33	.44	4.38	4.92	6.58	.49	4.48	5.55	7.26	.53	4.56	6.06	7.93
4	.33	4.66	4.46	5.48	.48	4.96	6.53	7.95	.53	5.06	6.87	8.36	.60	5.20	7.7	9.32
4½	.34	5.18	5.15	5.73	.49	5.48	7.43	8.2	.55	5.60	7.96	8.77	.64	5.78	9.2	10.1
5	.35	5.70	5.85	6.5	.50	6.00	8.35	9.18	.57	6.14	9.1	9.97	.68	6.36	10.8	11.77
6	.36	6.72	7.15	7.9	.51	7.02	10.07	11.03	.62	7.24	11.8	12.8	.75	7.50	14.15	15.28
7	.38	7.76	8.76	9.87	.52	8.04	11.9	13.29	.66	8.32	14.45	15.96	.83	8.66	18.15	19.83
8	.42	8.84	11.05	12.03	.52	9.04	13.5	14.7	.69	9.38	17.12	18.28	.91	9.82	22.65	24.3
10	.44	10.88	14.40	15.6	.59	11.18	19.0	20.48	.85	11.70	26.6	28.4	1.10	12.20	34.1	36.25
12	.48	12.96	18.72	20.18	.68	13.36	26.1	27.86	.98	13.96	36.4	38.84	1.24	14.48	46.0	48.94
14	.52	15.04	23.6	25.6	.78	15.56	35.0	37.72	1.13	16.26	48.8	52.54	1.44	16.88	62.0	66.48
16	.56	17.12	29.0	31.36	.88	17.76	45.0	48.39	1.25	18.50	61.6	66.26	1.65	19.30	81.5	87.22
18	.59	19.18	34.2	36.88	.97	19.94	56.1	60.3	1.39	20.78	77.0	82.78	1.87	21.74	104.0	111.13
20	.63	21.26	40.5	43.55	1.07	22.14	68.4	73.5	1.53	23.06	94.4	101.4	2.09	24.18	128.0	137.1
24	.69	25.38	53.2	57.8	1.25	26.50	95.6	103.62	1.82	27.64	134.5	145.7	2.48	28.96	183.0	196.5
30	.90	31.80	86.6	93.9	1.54	33.08	147.5	161.7	2.29	34.58	210.0	230.5	3.12	36.24	288.0	310.6
36	1.09	38.18	126.0	136.35	1.83	39.66	211.0	231.1	2.80	41.60	310.0	338.5	3.74	43.48	415.0	447.5

fibre. This type of pipe is not a patented product. The machines on which it is manufactured, however, have been patented by the Societa Anonima Eternit Pietra Artificiale of Genoa, Italy, which has licensed twelve companies throughout the world to use their equipment. Transite Pipe is manufactured in the United States under this machine use licensing arrangement. While the pipe as made in this country is basically the same as the Italian product, it has been adapted to conform to American practice. This applies particularly to length, diameter and wall thickness. It is made in four pressure classes in heads up to 462 ft. of water.

Working pressure in pounds per square inch and equivalent heads in feet of water are shown below for the four classes of Transite Pressure Pipe.

CLASS	WORKING PRESSURE	EQUIVALENT HEAD
	lbs. per sq. in.	*feet of water*
50	50	115
100	100	231
150	150	346
200	200	462

These classes, pressures and heads correspond in general to the universally accepted classification of cast iron pipe. For example, Class 150 Transite Pipe is designed for use under the same service conditions as Class 150 cast iron pipe.

The pipe is manufactured with plain ends in maximum lengths of 13 ft., and in sizes from 2 to 36 in. inclusive.* Each length of pipe is machined to a specified outside diameter for a short distance from each end to accommodate the couplings used for joining the pipe. The couplings used are of two types, namely, the field assembled Simplex and the factory assembled Simplex. These couplings are cut and machined from Transite tubes of the required size and wall thickness. The couplings are cylindrical in form and are provided with inwardly projecting shoulders on the interior of each end for the retention of the molded rubber rings which are used to seal the joint.

The factory assembled coupling, which is so called because it is installed on one end of the pipe in the factory, differs from the field

* Standard lengths are 5′ for sizes 2″ to 3½″; 6′ 6″ for size 4″; and 13′ for sizes 4½″ and larger. Dimension data are given in table 1.

assembled coupling in that it is provided with less clearance between the pipe and the internal shoulders and is slightly longer than the coupling used in field assembly. The coupling rings are of molded rubber composition and are round in form as well as in cross section. The inside diameter of the rubber rings varies from 4 in. for 4-inch pipe to 33 in. for 36-inch pipe, and from a thickness of 0.55 in. for 4-inch pipe to 1.00 in. for 36-inch pipe.

MANUFACTURE

Asbestos cement pressure pipes are manufactured from a mixture of asbestos fibre and Portland cement, the proportions being 15 percent and 85 percent by weight respectively. An excess of water is added to the fibre and cement and the whole is passed through a mechanical mixer. The resultant mixture is filtered through a revolving screen having a very fine mesh covering on which a uniformly thin film of the asbestos cement material is deposited. This film is then transferred in a continuous operation to an endless traveling felt belt where the excess moisture is extracted by means of a regulated suction. After this operation a thin film of asbestos cement remains on the felt. The felt carrying the film or sheet then enters the press section of the pipe machine and passes over a press roll and under the mandrel on which the pipe is formed and is transferred from the felt to the mandrel. The application of the film or sheet of asbestos cement is continued until the pipe reaches the required thickness as indicated by a gauge. The pipe is removed from the mandrel and a wooden core inserted and the pipe placed on a precuring rack. The core is for the purpose of maintaining the roundness of the pipe and specified dimensions during the precuring period. After adequate strength has developed from air curing, the pipe is cured by special process to develop its ultimate strength and other qualities which distinguish it from the conventional Portland cement composition.

After completion of the curing process the pipe is trimmed to length by carborundum wheels, mounted on a common frame so that both ends of the pipe are trimmed simultaneously. The pipe is then transferred to a second machine where the outside is machined from each end for the application of the couplings. Upon completion of the machining operations, each length of pipe is subjected to a hydrostatic pressure equal to double the rated working pressure. Four, six and eight inch pipe is tested for a loading equivalent to a

fibre stress of 2750 lbs. per sq. in. for the 4 and 6 in. pipe, and 3500 lbs. per sq. in. for the 8 in. pipe.

EXTENT OF USE

As previously stated, asbestos cement pipe has been used throughout the western part of Europe for the past twenty years. Up to the close of 1935, 16,415 miles of pipe had been placed in service as follows:

	miles
Italy	6,244
France	2,276
England	2,087
Spain	1,970
Japan	957
Belgium	850
Germany	634
United States	549
Austria	407
Czechoslovakia	221
Hungary	200

During the year 1936 a total of 254 miles of Transite Pipe was sold in this country, making a total of 803 miles for the United States at the end of 1936.

The conclusions of the report on Transite Pipe and couplings as made by the Underwriters' Laboratories, Inc., of the National Board of Fire Underwriters follow. While Transite Pipe is manufactured in sizes up to and including 36 in. in diameter, the Underwriters have listed, as with other types of pipe, sizes to 24 in. only.

"The following conclusions apply to Transite Class 150 pressure pipe and couplings in sizes from 4 to 24 in. inclusive, for use in underground water service where the working pressure does not exceed 150 lb. per sq. in."

PRACTICABILITY

"The pipe and couplings can be handled and shipped by the methods employed without excessive damage or breakage. They can be properly installed under conditions ordinarily met with in service, by those reasonably familiar with the installation of underground pipe; and repairs and renewals of Transite pipe lines can be accomplished without unusual difficulty."

"Examination of the pipe and couplings, a study of the materials

involved, and consideration of the methods regularly employed in handling and shipping this material, all show that it is practical to carry out the necessary handling and transportation without breakage or excessive damage. Where transportation by rail is involved, the pipe is loaded on cars and secured in a manner conforming with established regulations for such shipments."

"The Service Record investigation also shows that the pipe and couplings can be handled, shipped, and installed without breakage or excessive damage under customary practices, and the fact that large users of this material are consistently sending in new orders indicates that the pipe and couplings already laid are giving good service."

"Observation made during the tests at the factory and during field inspections of several Transite pipe installations show that it is practical for those reasonably familiar with underground pipe work to place this pipe in proper position in the trenches and assemble the joints. These observations also show that Transite pipe lines can be assembled with the ordinary tools, provided that they can readily be connected to existing cast-iron or steel water lines and that they can be installed under all conditions under which other types of underground pipe can be installed."

"The results of the Tapping Tests show that if a reasonable amount of care is exercised, it is practical to drill and tap directly into the wall of the pipe for service connections and that such connections are free from excessive leakage."

"The results of the Restrained Joint Tests show that the joints possess sufficient flexibility to enable the pipe to be laid to curves and the joints will withstand a reasonable amount of deflection after they are assembled, without leakage."

"A study of the form of the joint and observations made during the preparation of the test samples show that it is practical to remove and replace pipe sections in a manner similar to that employed in assembling the line. Observations during the tests show that the joints can be made tight against the pressure for which they are intended. The Service Record investigation showed that the pipe is giving good service in the field and that the joints are easily assembled and require no attention after the lines are laid."

DURABILITY

"The Transite Pipe and couplings dealt with in this report, when installed according to the methods advocated by the manufacturer,

will probably withstand deteriorating influences resulting from exposure to potable waters and ordinary ground conditions for long periods of time."

"The Service Record investigation shows that Transite pipe has been used in alkali soil for a period of four years without showing signs of disintegration. Two of the replies indicated that the pipe was being used successfully in conveying acid mine waters."

It is generally recognized that ordinary Portland cement products are attacked and disintegrated in relatively short periods of time by soils and waters containing soluble sulphates and weak acids. The manufacturer claims that the rate and extent of such disintegration is largely controlled by the free lime content of the composition and that Transite pipe differs from ordinary Portland cement products in that it has a very low free lime content and, therefore, has substantial immunity to such disintegrating agents."

"The results of the investigation of the chemical properties of Transite pipe show this product to differ from ordinary Portland cement compositions in that the pipe contains a much lower percentage of free lime and a correspondingly higher percentage of silica."

"The information relative to the durability of the pipe and couplings obtained during the tests and Service Record investigations shows that this pipe is not unduly susceptible to breakage in handling, transporting, and installation, and that it may be expected to withstand without undue breakage the stresses likely to be met with in the service for which the pipe and couplings are intended."

"Experience has shown that rubber used in underground joints has given long and satisfactory service, the life of the rubber being favored by the dampness and darkness conditions."

"The results of the Restrained Joint Tests show that the joint is capable of adjusting itself to expansion and contraction due to changes in temperature and to moderate lateral movement occasioned by shifting and settling of the soil."

"The Service Record investigation showed that the Transite pipe and couplings made by this manufacturer have been in service for periods over four years, and none of the replies received indicated that the pipe was not giving satisfactory service for the purpose for which it was used."

RELIABILITY IN SERVICE

"When properly installed, Transite pipe and couplings will withstand without failure, the stresses to which they will ordinarily be subjected in service. Due to the smooth glossy interior surface, the friction loss in this pipe is low and is likely to remain low indefinitely."

"The Service Record investigation indicates that the pipe and couplings have given good service under working pressures as high as 145 lb. There were no complaints either on the holding power of the joints or leakage under pressure."

"The results of the Restrained Joint Tests show that the joints will withstand considerable deflection without leakage. When the joints are properly restrained, they will withstand pressures sufficient to cause failure of the pipe."

"The examinations showed that the interior surface of the pipe is exceptionally smooth and glossy, thus decreasing the resistance to the flow of water."

"The pipe and couplings which have been in service have not developed any defects which would indicate that they are not reliable under the conditions met in ordinary mains for underground water service."

STRENGTH

"Transite pipe and couplings made in conformity with the specifications for its manufacture and installed according to the methods advocated are capable of withstanding the working pressures for which they are designed and all stresses to which they are likely to be subjected in service."

"The results of the Bursting and Tapping Tests show that the pipe and couplings have a minimum factor of safety of four, based on the maximum rated working pressure of 150 lb. per sq. in. While this factor is somewhat lower than in other types of listed pipe, it compares favorably with that required in iron body gate valves larger than 6 in. designed for the same working pressure."

"The results obtained in the Restrained Joint Tests show that the pipe can be deflected to a very considerable extent without causing any appreciable leakage at the joints, indicating that the flexibility of the joints and the strength of parts and assembly are such as to prevent leakage or material injury under lateral deflection resulting from settlements likely to occur under ordinary conditions."

"The Service Record shows that Transite pipe and couplings used in underground water service in a number of municipalities have proven reliable in service and none of the replies received indicated that this material was lacking in strength under the service for which it was used."

"The results of the Flexural and Crushing Tests show that the pipe will withstand without failure lateral loads of considerable magnitude and if properly bedded in the trench will probably sustain all external stresses due to trench loading that it is likely to be subjected to in service."

"The results of the Impact Tests show that the pipe is not unduly susceptible to breakage from impact."

UNIFORMITY

"The facilities and methods employed in the manufacture of the pipe and couplings which are the subject of this report are such as to insure an accurate and uniform product. The uniformity with which the pipe is assembled under practical conditions in the field will be dependent upon the experience of those doing the installation work, the extent to which the instructions for installation and handling are complied with, and the thoroughness of the tests and inspections after the pipe and couplings are laid.

"Examination of the pipe and couplings shows that a high degree of uniformity is obtainable. The external and internal diameters are uniformly concentric and the pipe is straight. No marked variation in the smoothness of the interior or exterior surfaces was found in the examinations."

"The examinations at the factory indicate that the facilities, method of manufacture, and of inspection and testing at present employed are such that the pipe can be produced in a manner comparable to that of other listed types of pipe."

"The examinations shows that the design of the pipe and couplings is such that the pipe can be uniformly and easily assembled. The Service Record investigation showed that persons accustomed to handling and laying underground pipe can handle and lay Transite pipe in a uniform manner without encountering any difficulties other than those common to other kinds of underground pipe."

"Observations during the preparation of the test samples and during the tests show that the pipe and couplings can be made uni-

formly tight at pressures considerably in excess of the working pressures."

SUMMARY

"From the conclusions drawn it will be noted that it is practical to handle and ship the pipe and couplings and install and maintain them in underground piping systems; that systems constructed of them are not subject to rapid deterioration; that the pipe and couplings are capable of withstanding all reasonable stresses to which they are likely to be subjected under ordinary service conditions; that they are reliable in service; that they are uniformly made and can be uniformly assembled."

This is submitted as a progress report for information with the recommendation that the committee be continued.

Respectfully submitted,
Sub-Committee 7-T
William D. Hurst,
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WATER WORKS—FINANCING AND RATES*

By C. C. Ludwig

(*Executive Secretary, League of Minnesota Municipalities*)

Before outlining the various means of financing water works systems, it will be helpful to consider what it is that we must finance. A going water works system consists essentially of two parts: first, fixed plant which is by far the largest portion of the investment, and second, working capital which consists of the equipment, materials and supplies and working cash necessary to make use of the fixed plant. In the parlance of the water works business, fixed plant facilities are customarily divided into the following subdivisions:

Supply (wells or surface supply including any transmission lines necessary)
Treatment plant
Storage (low or high level reservoirs)
Distribution system (mains, valves, hydrants, services, meters, etc.)
Service facilities (office, shop, yard, garage, etc.)
Pumping facilities (this is listed separately for practical reasons, although pumping is often used in connection with the first four subdivisions above)

In acquiring and operating a water works system consisting of some or all of the categories mentioned previously, the municipal governing bodies must consider two phases of cost. In the first place there is the Capital Cost, which is the cost of constructing or acquiring the fixed plant and working capital. When a water works enterprise is first undertaken, this may mean the payment for the construction of a new system or for the purchase or condemnation of an existing system. After the enterprise has gotten under way, it becomes necessary to construct additions or extensions to the plant from time to time. In paying for all these capital costs,

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municipalities must use some type of installment payment plan. If cash revenues are collected in advance of spending, it is an installment "pay-as-you-go" plan. If the money for construction is spent before it is received in the form of cash revenue, it becomes necessary to use the installment-borrow plan.

In the second place, municipalities must meet the Current Cost of their water works which covers the following annual elements of expense:

1. Operation and maintenance of plant, plus administration and overhead cost.
2. Annual fixed charge for capital. This annual fixed charge for capital is present in every water works system whether or not it is calculated and whether or not it is met by adequate revenues. This annual fixed charge may be met in various ways.
   (a) If the municipality is on the "pay-as-you-go" plan, the annual construction and extension projects financed out of current revenue may approximate the correct annual charge for capital. On the other hand, it may be either more or less than the correct annual charge.
   (b) If a municipality uses the borrowing plan for financing its capital costs, the annual payments made for retirement of the water works debt plus interest on it may approximate the correct annual fixed charge for capital. On the other hand, this also like (a) above may be more or less than the correct annual charge.
   (c) There may be a combination of "pay-as-you-go" and borrow plans for meeting capital expenditures, but in any case it is desirable to calculate what an appropriate annual capital charge should be for each water works system.

An annual fixed charge for capital will cover roughly the following items and the following percentages of the capital valuation of the water works is shown on opposite page.

This 8 percent of capital valuation seems to approach the average practice where annual fixed charges for capital are calculated for the purpose of rate analysis. This is the type of current cost analysis which regulatory commissions require privately operated water utilities to make and which is the basis for the determination of reasonable rates. Municipal utilities are seldom subjected to legal regulation, but it is good business nevertheless for municipal governing bodies to apply such a cost analysis to their own enterprises.

	If retirement calculated on basis of 40 yrs. ave. life and 4% s. f. earnings	
	Straight line method	Sinking fund method
Interest on outstanding debt plus return on equity advanced by taxpayers	3½%	5%
Depreciation	2½%	1%
Taxes	1%	1%
Insurance, Contingencies, etc.	1%	1%
Total percentage of capital valuation	8%	8%

THREE MEANS OF FINANCING

There are essentially three final or ultimate means of financing water works costs: first, general taxes; second, special assessments or benefit charges; and third, water rates. When a community finds it necessary to provide funds for water works investment through the use of the public credit or borrowing, the ultimate means of financing is not changed. The revenues must come in, finally, from the three sources mentioned. Borrowing merely anticipates the later collection of the revenues.

TAXES

Property taxes are not generally used in the United States as a means of financing water works costs, although in many states the legal authority to do so exists. In Minnesota a substantial number of cities make a partial use of this revenue. Taxes are used much more generally in England than in this country. Where taxes are used, the emphasis is on the health aspect of a water works system rather than on the commodity aspect. In other words, all citizens are expected to contribute toward the support of the community water works according to their tax paying ability, because it is an essential sanitary and health service of the community. In some respects, it is like community education or a community sewerage service financed out of general taxes.

SPECIAL ASSESSMENTS

Special assessments or benefit charges involve a theory somewhat contrary to property taxes. The cost is distributed among the citizens of the community according to their direct benefit from the

enterprise rather than according to their general tax paying ability. Special assessments are usually levied to pay for the cost of water mains. These may be carefully calculated benefit assessments or arbitrary frontage taxes. Service connections between the public water mains and the plumbing systems of the private consumers may be directly paid for by the consumers or charged for on a price or reimbursement basis. Meters, similarly, may be financed privately or by paying to the municipality an installation charge. Whether they are special assessments, frontage taxes or installation charges, they all involve the same legal theory, namely, that those benefited should pay according to that benefit.

There are several advantages to the use of special assessments in financing at least a part of the cost of water works extensions, particularly lateral mains. A water main laid in a public street in front of a vacant lot unquestionably adds to the value of that lot and the levying of a special assessment against the lot recovers a part of this increased value which has been created by the public improvement. Then, too, the special assessment is a practical method of recovering a part of the fixed plant investment which is necessary to serve the consumer, regardless of the amount of water that may be taken by him. Similarly, if the special assessment is large enough to include the full cost of mains and their appurtenances, a substantial portion of the investment necessary for adequately fighting fires may be recovered. These substantial investments, to be ready to serve customers and to be ready to fight fires, will be more fully discussed later.

A frequent disadvantage in the use of special assessments obtains where the local special assessment procedure relies too much on the local option of the benefited districts. Some municipalities may not have the right, or may not deem it politically expedient, to proceed with water main extension projects unless petitioned for by a majority of the benefited property owners who are to be assessed. This restriction may result either in retarding desirable extensions or, in the case of speculative real estate developments, in too rapid an expansion.

WATER RATES

The third type of revenue for meeting water works costs and the one most commonly used in the United States is the water rate. In a few instances "flat" rates are still used, but meter rates are almost

universal, particularly in the larger cities. The metered water rate is the typical American method of financing a utility commodity or service which is sold to consumers. It is a price designed to recover from the consumers the cost of the service and charged at the time when the service is used. In other words, an adequate water rate may be designed so that the water utility may be completely self-sustaining on a price basis. This is its primary advantage. There is a disadvantage, however, in relying wholly on water rates. For water rates to be properly constructed and to recover the complete current costs of water, including the annual fixed charges for capital, means the inclusion of substantial service or "ready to serve" charges. Such service charges, while proper and scientific, are often difficult to explain and "sell" to the consumers. The political difficulties of the situation often result in the adoption of unscientific rates.

Finally, a municipality may use not one but several of the foregoing types of water revenue with a view to minimizing the disadvantages of each.

BORROWING

Where a community cannot follow the "pay-as-you-go" policy in meeting its capital costs, borrowing may be necessary. American practice, and in general the law in most American states, limits the use of borrowing, at least long term borrowing, to capital purposes. This involves the principle that the period during which a debt is repaid should not exceed the reasonable life expectancy of the improvement (well, pump, reservoir, water main, etc.) which is built from the proceeds of the sale of the obligation.

A borrowing policy has some advantages. It obviates the necessity of deferring immediate needs as is sometimes true where the "pay-as-you-go" plan is followed. It also provides an automatic allocation of the capital costs over a period of years. Serial bond retirements are usually spread quite evenly over the years. And bond payments coming due each year cannot be evaded. Optional reserve funds, on the other hand, are rather risky and may be neglected or not adequately safeguarded by politically minded governing bodies.

The major disadvantage of borrowing, of course, is the bitterness that often goes with the referendum election voting and the emphasis on cost rather than service. The interest which must be paid for the borrowing privilege is also a factor to be considered, although,

as far as the economic effect on the consumers is concerned, it makes little difference whether the municipality borrows the money and pays interest for him over a period of years or whether he puts up the money in advance and deprives himself of its earning power in private investment.

RATE STRUCTURES

Engineers who analyze water works costs for the purpose of building appropriate rates usually divide water works costs, both capital and current, into three elements as follows:

(1) Readiness to serve customers. This is the portion of the plant or cost which is required to be ready to serve the customers whether they use much water or little water. It covers the cost of a meter, the cost of a service and most of the cost of a system of mains as well as a substantial portion of the storage facilities.

(2) Readiness to serve fires. A water works system provides for two basic community services, first, a supply of safe water to the water consumers, and second, a system of fire protection which must, of course, be supplemented by a mobile fire department and fire equipment. To meet this second purpose it is obvious that water mains have to be larger and heavier, that pressure has to be greater, that storage facilities have to be larger, and that hydrants have to be installed. It is, of course, difficult to distinguish automatically between readiness to serve customers and readiness to fight fires, but the two purposes need to be separately emphasized.

(3) Provision of water. Some aspects of the water works investment, and particularly operating costs, are more closely related to the quantity of water taken by the consumers than to any other factor. The current cost of pumping is the best example of such "water" cost.

It is customary for two of the foregoing three elements of cost to be covered in designing a meter rate, namely, the readiness to serve customers and the provision of water. The readiness to fight fires is ordinarily recovered from the general fund of the municipality or whatever fund is used to finance the fire protection service of the community.

A. W. W. A. RECOMMENDED RATE FORM

The New England and American Water Works Associations have studied the makeup of water rates and recommended a certain type

of rate structure as involving correct general principles. The first thing to note about the recommended form is the presence of a substantial service charge. This is recommended as preferable to a minimum charge, because the latter discriminates between consumers of negligible quantities and of substantial quantities of water. It is recommended that the service charge be varied according to the size of the meter used in the individual services so that, for example, a five-eighths inch meter might have to pay a service charge of fifty cents a month, while a two-inch meter might be required to pay a three or four dollars per month service charge. In addition to a service charge, the recommended rate includes prices for the quantity of water used, as measured by meter.

The brackets or "slides" of this rate, and the recommended ratios for the spread of the prices, are briefly outlined as follows:[1]

> "On May 24, 1923, a standard form of rate schedule was adopted by the American Water Works Association, containing a service charge, and three slides, with a fourth or special rate for large manufacturers if deemed desirable. The adopted form is practically identical with the standard of the New England Water Works Association, adopted in November, 1916. The three slides are for convenience called, Domestic, Intermediate, and Wholesale or Manufacturing Rate. The quantities under each rate may be summarized as follows:

	(1) AT DOMESTIC RATE, FIRST	(2) AT INTERMEDIATE RATE, NEXT	(3) AT MANUFACTURING RATE, ALL OVER
Quantities in gallons			
Bills Annually	300,000	2,700,000	3,000,000
Bills Quarterly	75,000	675,000	750,000
Bills Monthly	25,000	225,000	250,000
Quantities in cubic feet			
Bills Annually	40,000	360,000	400,000
Bills Quarterly	10,000	90,000	100,000
Bills Monthly	3,300	30,000	33,300

[1] From "Water Works Practice Manual," American Water Works Association, 1926, pp. 460, 462, and 463.

Lower bracket meter rates for Minnesota municipal water supplies, source, treatment and financing

CITY OR VILLAGE	POPULATION, 1930	SUPPLY	TREATMENT PLANT	MAINS FINANCED BY: (1) SPEC. ASSESS. (2) RATES (3) TAXES	METER RATE FOR LOWER BRACKET: Water price	Minimum	Service charge for ⅝" meter	Discount for prompt payment	SAMPLE NET BILL FOR 1000 CU. FT. (OR 7500 GAL.) QR. ⅝" METER
Minneapolis	464,356	surf.	yes	SA; 6" lat; rates	$0.75 M cu. ft.—flat	$1.00 qr.—⅝"		15% pen.	$1.00
St. Paul	271,606	surf.	yes	SA; $1 ft.; rates	.90 M cu ft.—to 10,000		.75 qr.	10%	1.48
Duluth	101,463	surf.	yes	SA; begin; rates	1.50 M cu. ft.—to 10,000	.50 mo.—⅝"			1.50
St. Cloud	21,000	surf.	yes	SA	2.00 M cu. ft. to 4,000	$1.00 qr.—⅝"		10% pen.	2.00
Winona	20,850	well		rates	.30 M gal. to 15,000	2.25—⅝"		20%	1.80
Rochester	20,621	well		rates; taxes?	2.50 M cu. ft. to 6,000	1.50 qr.			2.50
Hibbing	15,666	well	part.	rates	.15 M gal. to 150,000	.85 mo.			1.12
Mankato	14,038	well		SA	1.00 M cu ft. to 1,200	1.20 qr.			1.20
Faribault	12,767	well		taxes	3.00 M cu. ft. to 15,000	.50 mo.			3.00
Austin	12,276	spring		rates	3.33⅓ M cu. ft. to 600; $1.50	$2.50 qr.		5–25% quan.	2.60
Virginia	11,963	well	part.	rates	1.25 M cu. ft. to 10,000	$0.50 mo.		.10M	1.40
Brainerd	10,221	well	part.	rates	.50 M gal. to 120,000	.75 mo. (net)		10%	3.37
Albert Lea	10,169	well	part.	rates	2.50 M cu. ft. to 15,000	2.50 qr. (gro.)		10%	2.25
So. St. Paul	10,009	well		SA	.22 M gal. to 50,000	.66 qr.			1.65
Red Wing	9,629	well		rates	2.00 M cu. ft. to 6,000	.40 mo.	.20 mo.	10%	2.34
Fergus Falls	9,389	surf.	yes		.10 M gal. flat		1.00 qr.		1.75
Chisholm	8,308	well	yes	taxes	.25 M gal.				1.87
Owatonna	7,654	well			2.50 M cu. ft. to 2,000	1.75 qr.			2.50
Moorhead	7,651	well			3.00 M cu. ft. to 3,000	1.00 mo.		10%	2.70
Eveleth	7,484	surf.	yes	rates	.15 M gal. to 150,000				1.12
New Ulm	7,308	well			.50 M gal. to 5,000 (next 3,000, .45)	.50 mo.			3.75
Bemidji	7,202	well		rates; taxes?	.30 M gal. to 20.000	2.00 qr.		5%	2.14
Stillwater	7,173	well		SA; 75c ft.; taxes	.20 M gal. to 30,000	2.00 qr.			2.00
Cloquet	6,782	well	part.		.50 M gal. to 3,000 (next 12,000, .40)				3.30

Crookston	6,391	surf.	yes		.65	M gal. to 3,000 (next 3,000, .45) (next 9,000, .40)	.65 mo.			3.90
Willmar	6,173	well		SA	2.50	M cu. ft. to 1,000	.75 qr.			2.50
Ely	6,156	surf.	yes	taxes	2.50	M cu. ft. to 3,000	.72 mo.		10%	2.25
Columbia Heights	5,613	purchase		SA	.15	M gal. flat				1.12
Fairmont	5,521	surf.	yes	SA; $1 ft.; taxes	3.00	M cu. ft. to 1,500			10%	2.70
Hastings	5,086	well		rates	.367	M gal. to 7,500	2.75 qr.		.50	2.25
International Falls	5,036	surf.	part.	taxes	.30	M gal. to 10,000	2.00 qr.		10%	2.03
Little Falls	5,014	well		rates	.40	M gal. to 10,000	3.00 qr.		.50	2.50
Anoka	4,851	well		SA; ½; rates; ½	1.50	M cu. ft. to 1,800	.50 mo.	MR, .15 mo.		1.95
St. Peter	4,811	well			.30	M gal. to 20,000	1.00 qr.		10%	2.03
St. Louis Park	4,710	purchase		SA	.16	M gal. flat				1.20
West St. Paul	4,463	St. Paul			.90	M cu. ft. to 10,000		.75 qr.	10%	1.49
Robbinsdale	4,427	purchase			1.60	M cu. ft. flat	2.00 qr.			2.00
Two Harbors	4,425	surf.	part.	taxes	No meter rate					
Montevideo	4,319	springs	part.	rates	2.10	M cu. ft. to 5,000		1.40 qr.	5%	2.00
Thief River Falls	4,268	surf.	yes	rates	.50	M gal. to 10,000	1.50 qr.			3.75
Northfield	4,153	well		taxes	1.50	M cu. ft. to ?				1.50
Worthington	3,878	well			.45	M gal. to 9,000	1.00 mo.			3.37
Alexandria	3,876	well			.30	M gal. to 5,000 (next 5,000, .20)	2.50 qr. (gross)		10%	2.25
Hopkins	3,834	well			.15	M gal. flat				1.12
Waseca	3,815	well			.30	M gal. flat				2.25
Detroit Lakes	3,675	surf.	yes		1.50	M cu. ft. to 1,200				1.50
Pipestone	3,489	well		rates; taxes?	1.00	M gal. to 2,000? (next 3,000, .60) (next 5,000, .50)				5.05
Crosby	3,451	well		rates	3.75	M cu. ft. flat				3.75
Hutchinson	3,406	well		taxes?	.25	M gal. to 90,000	1.00 qr.			1.87
Richfield	3,344	No mun. system								
Marshall	3,250	well		taxes	3.50	M cu. ft. to 1,000?				3.50
Lake City	3,210	well		taxes	2.50	M cu. ft. to 1,000?				2.50
Grand Rapids	3,206	surf. well	part.	rates	.30	M gal. to 5,000 (next 10,000, .20)				2.00
Edina	3,138	well			1.58	M cu. ft. flat				1.58

CITY OR VILLAGE	POPULATION, 1930	SUPPLY	TREATMENT PLANT	MAINS FINANCED BY: (1) SPEC. ASSESS. (2) RATES (3) TAXES	METER RATE FOR LOWER BRACKET: Water price	Minimum	Service charge for ⅝" meter	Discount for prompt payment	SAMPLE NET BILL FOR 1000 CU. FT. (OR 7500 GAL.) QR. ⅝" METER
East Grand Forks	2,922	surf.	yes	taxes	.67 M gal. to 1,500 (next 3,500, .60) (next 15,000, .40)	1.00 mo. (net)		5% on excess	3.95
North St. Paul	2,915	well		SA; rates	.37½ M gal. to 2,000.				1.87
Blue Earth	2,884	well			.30 M gal.				2.25
Litchfield	2,880	well		rates	2.00 M cu. ft. to 2,000	.50 mo.			2.00
No. Mankato	2,822	well			.20 M gal. to 22,500	.50 qr.		15%	1.28
St. James	2,808	well		rates; taxes?	.45 M gal. to 3,000 (next 2,000, .40) (next 5,000, .35)	1.25 qr.			3.02
Gilbert	2,722	surf.							
		well	yes	rates; taxes	.25 M gal. to 15,000	.75 mo.			2.25
Sauk Center	2,716	well		rates; taxes	.40 M gal. to 10,000?				3.00
Staples	2,667	well		rates	2.00 M cu. ft. to 4,000	1.00 qr.		None	2.00
Sauk Rapids	2,656	well		SA	1.87½ M. cu. ft. to 1,600				1.87
Luverne	2,644	well	temp.	taxes	5.00 M cu. ft. to 400 (next 1,100, 2.50)	2.00 qr.			3.50
White Bear Lake	2,600	well		rates; taxes?	2.00 M cu. ft. to 3,000	1.50 qr.	.30 mo.		2.90
Bayport	2,590	well		taxes	.25 M gal. to 10,000	2.50 qr.		10%	
Sleepy Eye	2,576	well			2.50 M cu. ft. flat				2.50
Tracy	2,570	well			3.00 M cu. ft. to 500 (next 300, 2.50) (excess 2.00)	2.10 qr. net	MR, .60 qr.	5% over min.	3.19
Nashwauk	2,555	well		rates	.33⅓ M gal. to 3,000 (next 2,000, .25; excess, .20)	1.00			2.65
Redwood Falls	2,552	springs	part.	SA; Intersec: rates; taxes	3.30 M cu. ft. to 3,000	.55 mo.		10%	2.97
Proctorknott	2,521	No mun. system							
Wadena	2,512	well			1.87½ M cu. ft. to 1,200				1.87

"The quantity of water covered by the first or domestic rate will include substantially all water used by private residences, and also much of the water used by small commerical and industrial establishments.

"In its report recommending the standard schedule, the A. W. W. A. committee expressed the opinion that the ratio between the first and third rate should be limited to about 2 to 1, and that where the fourth or special rate is used, the amount of slide between the first and fourth rates should not exceed the ratio of 3 to 1. It was further recommended that the second, or so-called intermediate rate in a three rate schedule be fixed at an amount midway between the first and last rates. Where water is expensive or hard to get, and the plant is working on a high load factor, the slide ratio should be lower than where water is abundant and a broader market for it needed."

ANALYSIS OF COSTS FOR RATE MAKING PURPOSES

When a rate structure needs to be developed or revised, the first essential is to make a complete analysis of water works costs, both capital and current, in order to get a breakdown according to the three theoretical factors mentioned previously, namely, (1) readiness to serve customers, (2) readiness to fight fires, and (3) provision of water. A sample of such an analysis of water works cost follows. The figures used in this sample are purely arbitrary and are given merely to show method. The analysis is divided into two parts: first, an allocation of the water works capital among the three factors mentioned, and second, an allocation of water works current cost among the same three factors. (See tables A and B.)

It will be obvious that this theoretical method of approach must necessarily be modified to take account of local factors. First, there is the actual makeup of the plant. In some instances there may be no treatment facilities and some may be more elaborate than others. Some systems may involve much more pumping than others. Some may involve transmission costs and expensive reservoir facilities. A second modifying factor is the portion of the system which is financed privately such as individual services and meters. A third modifying factor obviously is the use of special assessments and taxes for financing in addition to the meter rate revenue.

The summary revenue plan shown by the sample analysis above

indicates that on the average $8.75 per year per customer should be secured through the service charge portion of the water rate. This should vary according to size of meter and might start at fifty cents per month for a five-eighths inch size meter, going to a dollar per month for a three-fourths inch meter, and so on.

TABLE A

Allocation of waterworks capital

(Assumed capital value—$500,000)

	100% VALUATION	APPORTIONMENT AMONG FACTORS					
		Readiness to serve customers		Readiness to serve fires		Providing water	
		%	$1000	%	$1000	%	$1000
Fixed Plant							
Supply Works, Wells	$10,000					100%	$10
Pumping Facilities	30,000					100%	30
Treatment Plant	50,000					100%	50
Storage Facilities	70,000	50%	35	50%	35		
Distribution System							
Mains	220,000	70%	154	30%	66		
Hydrants	20,000			100%	20		
Services	40,000	100%	40				
Meters	20,000	100%	20				
Admin. and Service							
Buildings	20,000	70%	14	30%	6		
Working Capital							
Equipment, materials, supplies, etc.	20,000	70%	14	30%	6		
Total Capital	$500,000		$267		$133		$90

Because of arbitrary allocations, simple and rough apportionment can be made of capital like this: Readiness to serve customers—50%; Readiness to serve fires—25%; Water—25%.

The fire protection charge is in most communities arbitrarily paid on the basis of an annual rental charge per hydrant. This is quite unscientific, because it does not take into account the size of the pipes nor the spacing of the hydrants, but it is quite simple and is almost universally used. Of course, if special assessments for water mains are used, both the service charge in the water rate and the fire protection charge to be made against the general fund may be appropriately reduced.

TABLE B

Allocation of waterworks current cost

(Assumed annual cost—$100,000)

	100% CURRENT COST	APPORTIONMENT AMONG FACTORS: Readiness to serve customers		Readiness to serve fires		Providing water	
		%	$1000	%	$1000	%	$1000
1. Fixed Charge for Capital 8% of $500,000 value..	$40,000	50%	20	25%	10	25%	10
2. Operation Pumping Treatment	$33,000					100%	33
3. Maintenance Pumps Treatment Plant	4,000					100%	4
Reservoirs............	3,000	50%	1.5	50%	1.5		
Mains................	3,000	70%	2.1	30%	.9		
Hydrants............	3,000			100%	3		
Services..............		100%					
Meters................	3,000	100%	3				
4. Customer accounting, billing, meter reading (4000 customers at $1.50)........	6,000	100%	6				
5. General Overhead........	5,000	50%	2.5	25%	1.25	25%	1.25
Total Current Cost....	$100,000		35.1		16.65		48.25

Summary revenue plan

A. Readiness to Service Customers—to be recovered by service charge in water rate (or in part by special assessments for mains or installation charges or private ownership of services and meters).—Estimate 4,000 services average $8.75 year, $35,000.

B. Readiness to Serve Fires—to be recovered by charge against general fund for fire protection (or, in part by special assessments if large part of mains cost plus hydrants is included; also occasionally by private fire protection charges).—Estimate 400 hydrants at $40 year, $16,000.

C. Water—to be recovered mainly, by commodity price portion of water rate (also, in part, by meter or flat or estimated charges for public use other than fire).—Estimate 60,000,000 cu. ft. sold at .80 M cu. ft. net, $48,000.

The charge for the third factor of "water" should average eighty cents per thousand cubic feet in the foregoing example, but this likewise is an average and is the result of different prices applying

to the different slides or brackets. Following the A. W. W. A. recommendation for a two to one spread between three brackets, it is possible that the eighty cents average calculated in this sample rate analysis could be secured by a rate of one dollar per thousand cubic feet for the domestic bracket, a rate of seventy-five cents per thousand cubic feet for the commercial bracket, and a rate of fifty cents per thousand cubic feet for the industrial bracket. The probable return, however, can be estimated only by applying proposed rates to actual customers.

LEGAL AUTHORITY IN MINNESOTA FOR FINANCING WATER WORKS

The authority to finance water works in Minnesota is derived from a multitude of enabling statutes supplemented by the provisions of many home rule charters. The state statutes are in some instances general, that is applicable to all classes of municipalities, but in many instances are applicable only to particular classes of cities, or villages. In general, there seems to be sufficient legal authority for the use of general taxes, special assessments and water rates or any combination of these three, in financing the costs of Minnesota municipal water works. Authority to borrow money for water works purposes likewise seems to be ample in the enabling statutes. There are several instances where enabling authority seems to authorize limited obligation or mortgage bonds as distinguished from full faith and credit or general obligation bonds. The interpretation of this authority is, however, doubtful and in practice very little use has been made of the limited obligation bond unless specifically authorized in a home rule charter.

There seems to be no limitation in the laws of the state that would require rates to be on a self-sustaining basis or that would prohibit them from being profitable. There is very little limitation upon the subsidizing of water works funds out of general taxes or, on the other hand, upon the transfer of surpluses from utility funds to general funds. These surplus and deficit transactions may be accomplished either by direct transfers or through the failure to make payment for fire protection costs, overhead costs, etc. The business principle that a water works should be self-sustaining, receiving credit for all services rendered to the general public and other departments and being charged for all services rendered to it, may be

carried out or not, as the governing body in charge of the water works sees fit.

MINNESOTA PRACTICE

The water works financing practice in Minnesota cities does not follow a particular mold. On the whole the municipal water utilities appear to be self-sustaining, although in quite a few instances tax subsidies of one kind or another are received. In 1936 a WPA survey was made of the seventy cities and villages in Minnesota between 2,500 and 25,000 population (WPA survey No. 2518, sponsored by the Municipal Reference Bureau of the University). For most of the cities in this group an analysis was made of the water works receipts and disbursements in the year 1935. While this analysis is not too reliable and the figures have not been subjected to auditing and check, a rough idea of the amount of the water works transactions may be gained from the summary table shown on page 632. The first column in this table shows the water works receipts from the sale of water; the second shows the total receipts excluding the proceeds of borrowing; the third column shows the disbursements for operation and maintenance purposes; and the fourth column shows the total disbursements excluding borrowing payments. In the second and fourth columns some cash equivalents have been included to take account of unremunerated services to other funds.

The table on pages 624–626 briefly describes the water works systems in this same group of seventy Minnesota cities, as well as the three first class cities, indicating the source of supply, whether there is a treatment plant and whether special assessments and taxes are used for financing as well as water rates. The same table includes an analysis of the lower bracket of the water rate and a sample quarterly bill for an assumed customer using a five-eighths inch meter and taking one thousand cubic feet of water during a quarter. While it could not be determined in some instances in calculating this sample bill whether the prompt payment discount applies to gross or net figures, it is to be assumed that the prices given are approximately correct. The table indicates the wide range of cost as it is practiced in Minnesota. Of course, the cost of producing and distributing water varies greatly throughout the state. The other supplemental means of financing also have much to do with the meter rate price.

Summary of water receipts and disbursements in selected Minnesota municipalities for the fiscal year 1935

Information from W. P. A. Project 2518, a survey of local government in 70 Minnesota municipalities

MUNICIPALITY	POPULATION 1930	RECEIPTS FROM		DISBURSEMENTS FOR	
		Sales of water	All sources except borrowing	Operation and maintenance	All purposes except borrowing
St. Cloud	21,000	$65,123.80	$73,171.02	$38,544.59	$87,103.74
Winona	20,850	67,887.30			51,631.65
Rochester	20,621	87,940.50	99,303.03	42,409.37	68,298.77
Hibbing	15,666	88,962.44	104,627.60	104,627.60	104,627.60
Mankato	14,038	39,144.11	47,226.87	26,456.59	44,234.94
Faribault	12,767	48,702.92	85,390.63	49,124.06	65,197.57
Austin	12,276	48,447.28	48,788.57	11,135.67	36,701.72
Virginia	11,963	22,070.61	28,843.83	32,728.81	66,243.88
Brainerd	10,221	53,404.70	72,315.03	28,951.38	81,558.50
Albert Lea	10,169	42,783.52	48,750.59	24,460.16	42,243.51
South St. Paul	10,009	24,562.44	30,794.92	24,793.80	31,680.30
Red Wing	9,629	27,594.21	36,993.12	12,126.09	36,575.18
Chisholm	8,308	26,653.24	54,240.12	49,911.60	70,694.16
Owatonna	7,654	30,589.07	32,074.11	20,005.29	48,782.43
New Ulm	7,308	29,228.70	31,315.40	12,243.11	19,053.11
Bemidji	7,202	14,646.14	15,695.39	9,975.56	19,810.33
Stillwater	7,173	19,904.15	23,571.96	19,139.66	27,135.58
Willmar	6,173	16,312.84	20,260.36	6,851.32	11,765.42
Ely	6,156	16,281.48	39,177.38	39,177.38	39,177.38
Columbia Heights	5,613	9,151.50	9,855.02	10,301.99	10,331.31
Fairmont	5,521	29,382.54	41,846.59	21,560.91	41,846.59
Hastings	5,086	8,769.05	8,769.05	5,719.61	10,876.57
Little Falls	5,014	11,130.48		8,193.74	16,620.69
Anoka	4,851	7,906.59	7,981.13	4,884.04	8,544.61
St. Louis Park	4,710	5,810.38	19,520.41	6,227.64	19,520.41
Montevideo	4,319	18,860.00	22,175.66	10,666.88	20,183.90
Thief River Falls	4,268	14,987.39	15,946.06	5,145.51	19,356.31
Northfield	4,153	10,172.17	10,227.72	6,016.04	12,307.80
Hopkins	3,834	4,835.56	6,133.41	4,861.37	10,070.62
Detroit Lakes	3,675	11,392.58	12,466.31	2,667.71	7,670.57
Pipestone	3,489	23,048.54	23,315.54	10,488.80	28,071.30
Crosby	3,451	11,632.49	17,921.55	5,258.71	14,308.16
Hutchinson	3,406	6,745.27	7,114.51	3,895.18	5,245.18
Lake City	3,210	8,018.90	8,018.90		
Grand Rapids	3,206	15,112.88	16,801.38	14,953.14	15,373.12
East Grand Forks	2,922	17,800.31	19,519.81	9,816.32	19,519.81
North St. Paul	2,915	6,909.69	7,574.56	3,604.69	5,487.92
Blue Earth	2,884	9,553.76	13,139.94	6,155.56	6,155.56
Litchfield	2,880	6,333.48	6,333.48		

MUNICIPALITY	POPULATION 1930	RECEIPTS FROM		DISBURSEMENTS FOR	
		Sales of water	All sources except borrowing	Operation and maintenance	All purposes except borrowing
North Mankato	2,822	4,635.32	4,922.51	1,305.20	3,416.10
St. James	2,808	9,817.42	9,817.42		
Gilbert (Water and Light comb.)	2,722	37,609.80	43,539.64	42,170.95	138,019.91
Sauk Center	2,716	11,621.64	15,199.08	7,235.85	13,589.27
Staples	2,667	4,383.91	4,868.21	5,215.99	9,090.55
Sauk Rapids	2,656	5,259.23	5,259.23	1,962.45	5,259.23
Luverne	2,644	10,191.05	10,244.94	1,108.80	
White Bear Lake	2,600	8,135.17	8,160.17	4,327.65	7,586.30
Bayport	2,590	3,029.35	7,479.85	2,079.95	5,109.95
Nashwauk	2,555	8,168.61	11,219.20	11,989.69	
Redwood Falls	2,552	9,855.70	11,077.50	5,498.63	7,966.65
Wadena	2,512	6,992.08	6,992.08	2,903.77	

According to available information it appears that in the municipalities above 2,500 at least eight use service charges in their water rates, as follows:

St. Paul—Pop. 271,606

$.75 quarter .... ½ and ⅝" meter
1.05 quarter .... ¾" meter
1.80 quarter .... 1" meter

$.85 month .... 1¼" meter
1.10 month .... 1½" meter
2.25 month .... 2" meter
5.00 month .... 3" meter
10.00 month .... 4" meter
20.00 month .... 6" meter
35.00 month .... 8" meter
50.00 month .... 10" meter

Red Wing—Pop. 9,629

$.20 month .... ⅝" meter
.30 month .... ¾" meter
.40 month .... 1" meter
.75 month .... 1½" meter
1.00 month .... 2" meter
1.50 month .... 3" meter (comp.)

Fergus Falls—Pop. 9,389

$1.00 quarter	⅝″ meter
1.70 quarter	¾″ meter
2.70 quarter	1″ meter
3.70 quarter	1¼″ meter
5.00 quarter	1½″ meter
8.00 quarter	2″ meter
12.00 quarter	2½″ meter
16.75 quarter	3″ meter

Anoka—Pop. 4,851

Meter rental .... $.15 month

West St. Paul—Pop. 4,463

St. Paul supply; same rates and service charges as St. Paul.

Montevideo—Pop. 4,319

$1.40 quarter	⅝″ meter
1.80 quarter	¾″ meter
2.10 quarter	1″ meter
2.40 quarter	1¼″ meter
3.00 quarter	1½″ meter
6.00 quarter	2″ meter
12.00 quarter	3″ meter
18.00 quarter	4″ meter
24.00 quarter	6″ meter

White Bear Lake—Pop. 2,600

$.30 a month

Tracy—Pop. 2,570

Meter rental .... $.60 quarter

The municipalities using special assessments in whole or in part for financing the construction of water mains are as follows:

Minneapolis—Cost of 6″ lateral
St. Paul—$1.00 front foot
Duluth—Assessments levied, but half water receipts are later credited to assessment payments (assumes ½ rate covers 8% of value for interest, sinking fund and depreciation of mains)
St. Cloud
Mankato
South St. Paul
Willmar
Columbia Heights
Anoka (S.A. ½; Rates ½)
St. Louis Park
North St. Paul (part)
Sauk Rapids
Redwood Falls (all exc. intersections)
Stillwater ($.75 ft.)
Fairmont ($1.00 ft.)

DESIRABLE FINANCING PLAN AND RATES

In a theoretical sense it would seem that a reasonable financing plan for Minnesota water works systems to emply should involve the following points:

(1) There should be a substantial use of special assessments for financing the cost of standard six-inch mains, together with their appurtenances, including hydrants.

(2) Services should be financed privately for the portion inside the property line and by special installation charges for the portion in the streets.

(3) Meters should, if possible, be owned by the city with a moderate charge made for installation and subsequent charges for repairs necessitated by negligence of consumers.

(4) A meter water rate should be established which will approach as nearly as possible the scientific principles suggested by the A. W. W. A. This would include a moderate service charge and a moderate spread in the brackets and the price for water.

(5) There should preferably be no use of general taxation for the support of the water system, except to pay for the public use of water (such as for street sprinkling, sewer flushing, fountains, public building use, etc.) and to pay for the public fire protection charge which is not recovered through special assessments.

TRANSFERS BETWEEN WATER AND GENERAL FUNDS

The following transfers from the water to the general fund of the municipality may be justified:

(1) The water fund should pay for its fair share of the general city overhead and for any special services from other funds or departments.

(2) A payment should be made in lieu of taxes, at least in lieu of municipal taxes. If the water works is profitable and has established its own adequate replacement and contingencies reserve, then an extra transfer can be made as a total tax equivalent, the full amount going to the municipal general fund until or unless the policy of the state should require the payment of portions of this tax equivalent to the state itself or the appropriate county and school district governments.

(3) The water works should pay to the general fund a return on any equity which has been advanced to the water works by the

general taxpayers. This does not mean a return on the investment made by the special assessment payers or the water rate payers.

On the other side of the picture, it would seem appropriate that the general fund or any other benefiting fund should transfer to the water fund the following:

(1) A payment for the public use of water.

(2) A payment for general fire protection benefit not recovered by the water works from the benefited owners by special assessments or by private fire protection charges.

DESIRABILITY OF SEPARATE WATER FUND AND GOOD ACCOUNTING

It is an accepted principle of good practice that municipalities should establish separate funds for each of their utility enterprises. This means that there should be a separate water fund to take care of the receipts and disbursements of the water works business. In accounting for this fund appropriate accounts should be installed and used, following, if possible, the accepted classifications which have been developed by the industry in cooperation with the various regulatory commissions of the country. Such accounts should provide for a breakdown of the water works capital valuation and the current expenditures and revenues, so that the cost and rate analyses outlined in this lecture may be more easily made, when called for from time to time by the governing bodies of our municipal waterworks enterprises.

CONSTRUCTION OF SMALL WATER SYSTEMS*

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The problem of financing a small water works system is always a difficult one. This paper will be mainly devoted to water works systems in towns with populations ranging from 500 to approximately 2,000. However, some consideration will be given to towns having a population up to approximately 10,000.

The problems that confront an engineer in the design and construction of a water works system for the small town are in some aspects similar to those of larger towns or cities. But in many respects the problems are essentially more difficult as the engineer is more limited in money available and must design the plant and system so as to obtain satisfactory results at a very minimum of cost. The advantages of fire protection and the consequent lowering of fire insurance rates are always the main selling points of a water works system to a small town. In order to obtain the greatest reduction in fire insurance rates for such small towns it becomes necessary to install larger mains, larger treatment plant and larger pumping units than would ordinarily be installed for the furnishing of a domestic supply only. For this reason the per capita cost of a complete water works system for towns of 500 to 2,000 people is considerably greater than for larger towns and cities.

It is impossible to set an exact limit or standard as to the minimum size of town that can afford to build a water works or in which a water works will produce sufficient revenue to be self-sustaining and at the same time retire the construction costs. This depends upon the particular conditions involved and upon relative wealth of the inhabitants. It is undoubtedly possible in some cases to design and finance an adequate water works system for a town of 500 population, particularly if the town has available a satisfactory supply of well water that is not too hard and sufficiently pure and clear not to require filtration. But if a similar town were so located that it

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would be necessary to impound a supply and provide a filtration plant the cost would be, in all probability, so great that it would be impossible to finance the construction cost on a revenue basis.

Due to the fact that a great number of smaller towns have built water works systems through the aid of the Public Works Administration there will undoubtedly be in the next few years, even after this program ends, a number of towns of similar size whose inhabitants, observing the benefits from the water works in neighboring towns, will demand these advantages for themselves.

Upon observing the more modern treatment plants and water systems in the smaller towns and the consequent better final water, there will be a movement in the neighboring larger towns to rehabilitate their existing systems and treatment plants to bring them up to a more modern standard.

One of the most difficult problems in promoting water works in the smaller communities has been to persuade the inhabitants that there is a necessity or particular advantage in having a public water supply. It is somewhat like the story of the man who was approached upon the question of building a new jail and he said that if the old jail had been good enough for his father, it was good enough for him.

PRELIMINARY SURVEYS AND INVESTIGATIONS

The next step after having created a civic desire for water works is to make the necessary preliminary surveys, designs and estimates in order that the cost of financing may be definitely determined. In making the preliminary surveys it is necessary to determine the probable consumption of water, the available source of supply, and prepare a map of the town showing streets and houses, and establish satisfactory location for all structures. It is also desirable to determine whether or not rock will be encountered in the excavation for pipe lines and structures.

Source of supply. It is necessary to determine whether the source of supply will be surface or ground water. Samples from the proposed source of supply should be obtained and chemical and bacteriological analyses of the water prepared. After giving due consideration to the analyses of the water a decision can be reached as to the proper type of treatment plant. If the source of supply is potable ground water of low turbidity and of not too great hardness the only requirements for a plant may be the proper arrangement

for pumping and chlorination. If, however, the supply is surface water or water of any appreciable turbidity, proper arrangement for chemical treatment and filtration is indicated.

In case it is proposed to use surface supply and a river or stream is available, proper investigation should be made to determine whether the supply will be ample at all times. In case it is required to impound a supply it will be necessary to locate a suitable site for a reservoir having an ample contributory area. For small watersheds a stadia traverse should be made in order that the area of the watershed can be properly determined. For larger watersheds the area may be calculated from U. S. Geological survey maps if they are available. The catchment area should be ample to provide for a full supply in the reservoir even in seasons of low rainfall. The size of the reservoir should be ample to supply the community for a period of twelve to eighteen months after all allowances have been made for evaporation.

Distribution system. The preliminary design for a distribution system is necessary to decide on the type of distribution system which will be the most economical and satisfactory for the particular case under consideration. If the town is laid out in a more or less rectangular plan, the grid system is best suited and gives the greatest flexibility. Should the town not be in a rectangular plan, it will usually be necessary to use some other type of distribution system but in any case if it is possible to do so the principal lines in the system should form a loop in order that a failure of a part of the line or a valve will not interrupt the supply of water to the greater part of the town. The size of the various lines will be determined by the density of population which they are serving and by the demands for fire protection. In smaller towns the controlling factor is usually ample fire protection. Location of hydrants and valves should be shown upon preliminary plans and arranged so as to give proper fire protection and flexibility to the system. In order to obtain satisfactory water pressure for the system it is usually found desirable to build either an elevated steel tank or a concrete or steel reservoir located upon higher grounds adjacent to the town, and preferably on the opposite side of town from the pumping station. The size of this tank or reservoir will depend upon the daily water consumption, size of the high service pumps proposed and the amount of water necessary for fire protection.

Estimates of cost. The purpose of making a complete layout of

the system on preliminary plans is that accurate estimates may be prepared. The importance of an accurate preliminary estimate cannot be over-emphasized as it is essential that the cost of the project be accurately determined in advance in order to provide for adequate financing. Local conditions and labor costs vary so much that any preliminary estimate based simply upon a cost per capita or the cost per connection is of questionable value in determining the cost of the project. Cost data showing the cost per foot of mains in place on similar jobs is valuable but it is often necessary to make corrections for the local labor costs. Prices of valves, hydrants, valve boxes, pumps, meters, etc., can usually be accurately obtained from equipment concerns and the necessary labor cost added to these items. This is also true of elevated tanks, filter control equipment, chlorinators, chemical feed machines and mixing equipment. The most satisfactory way of estimating structures is to make an accurate take-off of the quantity of materials involved and break this estimate down into its various items adding the labor cost to the material cost. Excavation, except that necessary for the distribution system, should be taken off in cubic yards and proper price determined for the community in which the project is contemplated.

In making up the necessary estimates it is very important to refer to a check list in order to be sure that no items of cost have been overlooked as it is very difficult under the usual methods of financing to raise additional money after a bond issue is floated and sold. To the construction cost should be added all overhead items such as engineering, legal and administrative costs, lands and rights-of-way, and any miscellaneous costs that may be encountered. It is also necessary to set up a contingent item in the estimate to take care of costs that may arise due to unforseen difficulties in the construction. The amount of the contingent item to be set up will not necessarily obtain on all jobs and it is hardly possible to say what percentage would be suitable without considering special conditions to be encountered on any particular project.

Public financing. In the past few years the greater proportion of small water works systems that have been constructed have been financed through the Public Works Administration, either by loan and grant or grant only. It is undoubtedly true that due to the Public Works Administration's assistance many of the smaller towns have obtained water works systems when they could not have done

so otherwise or at least could not have obtained so adequate a system with other methods of financing.

It is improbable that the Public Works Administration will continue to finance projects of this type over any considerable period of time. Therefore, we must give some consideration to the financing of projects without the aid of the Federal Government.

While it is possible to finance the cost of a water works system in any class city or town in Kentucky by general obligation bonds, this method of financing has possibly not been used at all in this state since the Water Revenue Bond Act covering such improvements became effective. Before the passage of this act it was virtually impossible for fifth and sixth class cities and towns to finance a municipally owned water works system. Our state constitution limits the amount of general obligation bonds that can be voted and sold in fifth and sixth class cities and towns to 3 percent of the assessed valuation of the town next preceding the year in which the bonds were voted. The assessed valuation of many good fifth class cities in Kentucky is less than $500,000.00. So it will be seen that the amount of general obligation bonds that can be voted in a city or town with no greater assessed valuation would generally provide for only a small portion of the cost of a water works system for such town or city. The Revenue Bond Act, which became effective in Kentucky in 1930, makes it possible for the smaller towns and cities to finance their water works systems even though the Federal Government discontinues assistance to this type of public improvement.

In order to make the system self-supporting and self-liquidating the revenue derived must be sufficient to pay operating costs, maintenance cost, cost of future extensions and to retire the bonds before the useful life of the system has expired. In setting the rates these factors must be kept in mind if the system is to be a success when put in operation. Some systems may operate on a much lower rate schedule than others and yet be self-liquidating. *However, few rates are comparable due to local conditions and the individual character of the town itself, therefore the rates of neighboring towns should not be given too much weight in establishing the rates for a proposed system.*

Private financing. A small water works system may also be financed by private interests, in case the rate of earnings of the system are sufficiently large in ratio to the total construction cost to interest private investors. In this case it will be necessary for

the city to grant a franchise to the water works company permitting it to lay and maintain its mains in the streets and alleys for a period of years. Under our present laws the rates for privately owned plants will be fixed by the Kentucky Public Service Commission.

Rate schedule. A minimum rate should be established with a downward sliding scale to take care of the large water users beyond the minimum amount. The rates must be sufficient to maintain the system on a self-liquidating basis and maintain a reasonable surplus. Rates can be established by a careful survey of the town after the cost of the project has been determined. In setting up the rate schedule it should be based on 100 percent metered service and the city should be required to pay a reasonable rental on all fire hydrants, public fountains and water used for washing streets and flushing sewers. If the financial schedule is based on the use of free water of various city departments, it will mean higher domestic, commercial and industrial rates and higher maintenance and operating cost.

Design. After the necessary funds have been raised for the construction of the project, final plans should be prepared. These plans should show clearly every item in the construction of the project together with all details that may be necessary to make plans entirely clear to the contractor. The plans should include a distribution system complete, showing the location of all valves and hydrants and also the elevated tank or reservoirs. In case it has been decided that a treatment plant is required, complete plans, sections and details should be shown. On these plans location of the pumps, chemical machines, chlorinators, etc., should be indicated together with the point of application of chemicals and chlorine to the water. Points of application should be arranged for flexible operation of the plant so that such chemicals as chlorine and ammonia can be applied either before or after filtration. From the chemical analysis of the water the proper chemical treatment should be determined. In case the conditions are such as to permit the location of the filtration plant at some point lower than the reservoir or the source of supply, low lift pumps will not be necessary as gravity flow can be obtained through the plant. However, if the source of supply is a stream, it will be necessary to have low lift pumps in order to lift the water to a sufficient elevation to flow through the plant.

Aeration. Many water supplies do not need aeration. Surface

supplies that have offensive tastes and odors should be provided with aeration to remove the dissolved gases resulting from decomposed organic matter. If, however, the offensive tastes and odors are due to dissolved organic matter, aeration will not be very effective. Aeration reduces the carbon dioxide content, eliminates the hydrogen sulphide and oxidizes iron.

Mixing and coagulation. The coagulants most commonly in use today are the combination of ferrus sulphate and lime or aluminum sulphate. Aluminum sulphate is more commonly used in this territory. Lime is also used in most of the treatment plants. If softening is required and particularly if the water has a high permanent hardness, soda ash may be necessary as well as lime. Proper feed machines should be provided for feeding the chemicals to the water in correct proportion. Common practice today is to use what is known as the dry feed machine.

For the small treatment plants for towns under 1,000 population it is rarely possible to install mechanical mixing and coagulating devices due to the lack of funds. In such small installations it is usually necessary to design some type of rather inexpensive mixing device, such as baffle chamber wherein the chemicals can be mixed with the incoming water and held in suspension for coagulation. The settling basin as a rule must consist of only one unit with one or more mud valve openings where the sludge can be drawn off periodically. Where funds are available for plants in towns and cities from around 1,000 to 10,000 population it is desirable to install a quick mixing basin with suitable mechanical mixing device with a detention period based on normal plant capacity of three to five minutes. It is also desirable to provide some form of mechanical coagulation equipment in order to obtain the best results with a minimum amount of chemicals. The coagulation basin in this case should be of such size that there will be a normal detention period for conditioning of from thirty to sixty minutes depending upon the characteristics of the water.

Sedimentation. Upon leaving the coagulation chamber the water should pass directly to a settling basin of such size as to provide a detention period of two hours or more, the final settling period to be determined by the characteristic of the water. In many cases, the detention period for the settling basin should be six to twelve hours.

In larger plants the settling basins may be constructed with me-

chanical sludge removal equipment and even in small plants this is sometimes found more economical than to provide duplicate units in order that the separate units may be cleaned without shutting down the plant. The depth of the coagulation and settling basins should be between 10 feet and 15 feet. The depth will depend somewhat on whether mechanical sludge removal equipment is used. Too shallow a tank is likely to cause scouring action which would distribute the settled sludge, while too deep a tank is of no particular advantage due to the slow velocity of settling of small particles of suspended matter.

Filtration. When the water leaves the settling basins it is carried directly to the filters. The type of filters best suited to smaller plants are rapid sand filters. The determination of the size and number of filter units will be based on first, the daily peak demand; second, the daily schedule of operation. A conservative basis of design should be used for the filter units. Ordinarily for small plants the design should be based on a capacity of two gallons per square foot of sand area per minute. It is not within the scope of this paper to go into the details of the filter construction and of sand and gravel graduations, other than to say that there are quite a number of types of filter underdrainage systems that are giving satisfactory results and the size and uniformity coefficient of filter sand is quite definitely established by practice in the profession. It is desirable that the filters be equipped with rate-of-flow and loss of head gauges in order that they may be operated satisfactorily.

After being treated with ammonia and chlorine or chlorine only as may be found best suited to the conditions of the particular plant under consideration, the water from the filters passes directly to the clear-well. The size of the clear-well will depend not only upon the size of the community served but also upon the amount of storage capacity in the elevated tank. The total storage capacity in the clear-well and elevated tank combined should not be less than required for 12 hours consumption. The clear-well and all storage reservoirs for filtered water in all cases should be covered so as to prevent any possible contamination of the water.

Washing filters. Steel, cast iron or concrete wash troughs are placed above the filter sand ordinarily at a distance of approximately 24 inches. The height from the sand to the over-flow edge of the wash water gutter should be equal to the vertical rise of the wash water in the filter that takes place in one minute. The wash

water gutters should be so arranged that the horizontal flow of the wash water does not exceed 3 feet.

Wash water for filters is best supplied by gravity from an elevated tank. For washing at high velocities the head at the strainer should be about 12 feet to 15 feet plus the head required for velocity and to overcome friction head of the underdrains; for low velocity washing the head should be less.

In the small plants it often becomes necessary, due to lack of funds, to utilize water from the main supply line for washing. In this case it is necessary that a pressure reducing and a pressure relief valve be inserted in the incoming wash water line adjacent to the filters. Another system for washing that is sometimes used is to furnish the wash water to the filters by means of a pump of proper capacity to take care of the needs.

It is believed that most engineers will agree that the conventional methods of washing rapid sand filters heretofore employed have not kept the beds in satisfactory condition. In numerous plants the operator has encountered serious difficulties in the cracking of the filter beds, the pulling of the sand away from the walls and the formation of mud balls in the sand bed. Experiments that have been run in the past two or three years have clearly indicated that an agitating force should be applied to the top of the sand bed to prevent the formation of mud balls and maintain the effective size of the sand grains. The surface wash is therefore being installed in several plants today to be used in conjunction with the conventional bottom or upflow wash. In the Covington, Kentucky, plant, which has recently been let to contract, surface washing of the filters, in addition to the conventional bottom wash has been provided. The surface wash is distributed through a system of laterals placed approximately 2 inches above the sand bed. The laterals are perforated so that the water travels in a horizontal direction from either side of the lateral. The surface wash is designed for a maximum capacity equal to a 10 inch rise. It is believed that this system of washing will be a great improvement over the conventional system that has been used for the past many years, as experiments and tests have disclosed that 90 to 95 percent of all foreign matter collected in the filter beds is in the top 6 inches of sand.

Pumping and storage. In most plants it will be found necessary to pump the water from the clear-well to the elevated tank or storage reservoirs. In communities where electric power is available,

electric pumps will be found the most efficient and best suited for this purpose. Pumps should be installed in duplicate units to provide for the possible break-downs and additional protection in case of fire. The capacity of these pumps will depend upon whether it is intended to operate them continuously or only a part of the day. It is found that in smaller communities it is much better to establish the size of the pump sufficiently large that from four to eight hours pumping will deliver the required amount of water, as pumps of larger capacity are usually much more efficient than those of very limited capacity. This method of operation will not require constant attention of the plant operator. Also in selecting the size of the pumps it is necessary to keep in mind the requirements of the National Board of Fire Underwriters, or rating boards, in order to obtain the best possible fire insurance rates for the community.

If the source of supply is wells it may only be necessary to provide proper chlorination and pumping units. In this case the only structure in connection with the plant would be a suitable building to house this equipment. However, if analyses should show the well water to have hardness greater than 100 parts per million, it might be desirable to include lime softening or zeolite treatment of the water. In any case a provision should be made for chlorination as a safe-guard to the health of the community even though the bacteriological analyses show no contamination of the water.

River intake. Where the source of supply is a river or large stream the installation of the intake structure is always a troublesome feature of a water works system for a small town. In some locations where there is a great variation between low and high water elevations, the installation of a dry well with centrifugal pumps is too costly to be considered. For instance, at some points on the Cumberland river in this state the variation from extreme high water to extreme low water is as much as 65 feet. Taking into account that the structure must be firmly anchored in solid rock there are some instances where a dry well would be as much as 80 feet in depth. To build such an installation including the pumps the cost would be prohibitive for a small town. There are two other types of intakes that can be considered, namely: vertical turbine pumps on tower or submersible type of pump. Due to the fact that the intake is such an important feature of a water works system the location and design deserve thorough study and consideration.

Landscaping. The plans should provide for landscaping and

beautification of the grounds around the plant. This will tend to create civic pride in the plant and also is conducive to better plant operation.

PLANS, SPECIFICATIONS AND CONTRACT DOCUMENTS

Complete specifications and contract documents should be prepared to accompany the plans. Specifications should definitely set out the materials and equipment to be used in the construction of the project. It is not within the scope of this paper to go into details concerning the specifications but it may be said that it is usually found more satisfactory to specify results rather than methods and that these specifications together with plans should be sufficiently complete that there will be no doubt in the contractor's mind as to the true intent of the engineer.

A small water works system may be constructed either by day labor or contract. Of the two, contract is to be preferred since it is possible to determine the cost of the project in advance. In either case it is necessary for the engineer to furnish competent supervision of the work in order to see that the intention of the plans and specifications is carried out.

CONSTRUCTION

In constructing the distribution system it is imperative that the lines be placed at sufficient depth to avoid the hazards of extreme cold weather. The ditches which are excavated for the purpose of laying lines should be of sufficient width to provide for proper caulking of the joints. Bottom of the ditch should be carefully shaped so that the pipe has an even bearing and in case of excavation in rock there should be 6 inches backfill of earth over the rock in order to provide a suitable bed for the pipe. The pipe should be carefully blocked behind tees and ells with stone or concrete in order to prevent lateral movement at these points due to water hammer. The most important point in the construction of the distribution system is tight joints; upon this will depend the economical operation of the entire system.

Two things are indispensable for a good joint, namely, that the entire amount of lead or joint compound necessary for the joint be poured at one time, and that the pipes be perfectly clean and dry where the joint material comes in contact with them.

Corporation cocks, curb stops and meter connections must be

water tight. The taps or connections to the main lines should be made in the top quarter section of the pipe for convenience in construction and also to avoid nuisance from material that may settle in the lower section of the pipe. All dead ends of pipe in the distribution system should be provided with a suitable drain or blow-off to remove stagnant water from the line.

Concrete structures designed to hold water or solutions such as coagulation and settling basins, filters and clear-well, should be constructed with every precaution to obtain waterproof concrete. The proportioning, mixing and placing of this concrete should be very carefully supervised by the engineer's representative. In order to secure a waterproof structure a dense, properly placed concrete is absolutely essential.

In the installation of dry feed machines, chlorinators, and mechanical equipment wherever used, it is preferable that the erection of this equipment be under the direction of the manufacturer's representative. Every precaution should be taken to properly line pumps, and check valves should be placed ahead of all high lift pumps.

Grounds surrounding the plant should be very carefully graded and planted with grass and suitable shrubs and trees as shown on the drawings.

STATISTICS

As is stated hereinbefore in this paper the per capita cost of water works systems may be used to some advantage in making quick preliminary estimates on other projects providing all conditions are taken into account. There are incorporated in table 1 certain data on eight complete water works systems and one filtration plant.

It will be noted that there is considerable variation in the per capita cost of the treatment plants in the smaller towns as compared with the treatment plant in Madisonville, Kentucky with population of approximately 7,000. The comparison being $17.20 for Eddyville as against $5.23 for Madisonville. However, in comparing the cost of the treatment plants in the four smaller towns listed above (2 to 6 inclusive) it is found that the average per capita cost is $14.76. As noted in the table above the cost figures represent construction cost only; when engineering, lands, rights-of-way, legal and administrative costs are added the total cost figures will be increased from ten to twelve and one-half percent.

In reducing the filtration plants to a cost per million gallons

capacity per day it is found that there is a very close relationship in the cost of the smaller plants on this basis. It is also found that the cost on this basis in the smaller plants compares very favorably

TABLE 1

NAME OF TOWN	CAPACITY	TYPE PROJECT	TOTAL COST OF PROJECTS NOT INCLUDING ENGINEERING AND OVERHEAD	COST OF TREATMENT PLANT	1930 CENSUS	PER CAPITA COST TREATMENT PLANT	PER CAPITA COST SYSTEM
	g.p.d.						
Madisonville...	1,000,000	Filtration plant	$36,112.74*		6908	$5.23	
Tompkinsville..	403,200	Com. W.-W. system	47,717.95	$13,510.71	850	15.89	$56.20
Burkesville....	403,000	" "	47,374.64	11,981.27	886	13.37	53.40
Eminence.......	432,000	" "	83,726.92	17,006.07	1323	12.84	63.00
Beattyville.....	403,000	" "	49,335.80	13,163.50	906	14.51	54.48
Eddyville......	400,000	" "	43,531.22	16,113.47	940	17.20	46.40
La Center......		" "†	33,082.18		537		61.70
Wingo..........		" "†	30,961.28		479		64.50
Arlington......		" "†	30,695.61		685		44.80

* This item does not include one piece of equipment which has not been accepted amounting to $1250.00.

† Project includes two wells; no treatment except chlorination.

All the above are P.W.A. projects with the exception of Madisonville.

TABLE 2

NAME OF TOWN	CAPACITY	COST PER MILLION G.P.D.
1. Madisonville..........	1,000,000 plus	$36,113.00
2. Tompkinsville..........	403,200	33,509.00
3. Burkesville..........	403,000	29,418.00
4. Eminence..........	432,000	39,366.00
5. Beattyville..........	403,000	32,646.00
6. Eddyville..........	400,000	39,963.00
7. Covington*..........	19,200,000	31,628.00

* Contracts let, construction work just starting.

with the cost of the larger plants. The information in table 2 has been taken from our records on seven plants, all of which are P. W. A. projects with the exception of Madisonville, and construction cost only has been used.

Average of towns 2 to 6 inclusive, which includes Tompkinsville, Burkesville, Eminence, Beattyville and Eddyville, $34,980.00. Average of all listed hereinabove $34,663.00.

OPERATION

The superintendent of a small town water works system is usually required to operate and maintain the entire system without assistance other than necessary common labor required for maintenance and repairs. The successful operation of the system will depend upon the experience, ability and industry of the superintendent. He should have a knowledge of chemical treatment and the purification of water and of the mechanical operation of the plant. He should familiarize himself with the location of all valves, hydrants and other connections in the distribution system and should keep an accurate up-to-date set of record plans of the system. It is his duty to see that services are metered and not permit the use of free water by the various city departments, individuals or corporations. All bills for water should be payable on or before a fixed date and if not paid within that time a penalty should be applied. However, it should not be expected that consumers can be carried indefinitely without discontinuing the service even though the penalty is applied. Since all water is sold on a credit basis, it is believed that for small systems the collection of bills at the end of each month is the best policy. For new services it may be necessary to make a service charge but this should not be greater than the actual cost of the labor and materials involved as it may have a tendency to discourage new consumers. All tenants should be required to make a deposit equal to at least the amount of one month's bill, deposit to be returned provided all bills are paid when the consumer wishes to discontinue the service.

The consumer will demand and is entitled to clear, odorless water, free from germ laden organisms and if the plant is successfully operated the demands of the consumer can be satisfied. The amount of chemicals will necessarily have to be varied with changes in the conditions of the water, therefore, the plant operator should at frequent intervals determine the correct quantities to be applied.

At the completion of the construction work the engineer should see that the plant is put into proper operation and in case the plant operator is without experience he should be carefully instructed as to his duties and advised as to emergencies that may arise. The

position of the operator of a small town plant should not be considered a political position; if it is the desire of the officials of a small town to employ a local man for the position, due care should be exercised in selecting the most capable man for the position, and he should be thoroughly trained in some modern treatment plant for a period of several months before he is allowed to take charge of the newly completed plant and water works system. While it is not usually done, it is desirable that the city make arrangements with the engineer to supervise the operation of their plant at intervals and see that it is being correctly operated. This would assure proper maintenance and careful operation of the plant. A small town water works system that has been designed with the proper consideration for the possible future growth of the town and with the best materials available, should with correct maintenance have a useful life of from twenty to fifty years. Parts of the plant and distribution system can be counted on to accomplish the purpose for which they are designed for at least a hundred years. Therefore, it can be readily seen that after construction, maintenance and operating costs have been retired, the city will continue to enjoy a substantial income from the ownership of their water works plant. This income may be used to either reduce taxes in the community or to finance projects for the community interest. In conclusion we trust that we have made it clear that there is a field for the design and construction of small water works systems worthy of the best efforts of the engineer.

DISCUSSION

H. K. BELL (*Consulting Engineer, Lexington, Kentucky*): In the discussion of so large a subject, I have the advantage of my predecessor in that he must necessarily undertake to cover the entire field, while I can select certain points of interest in his paper for more detailed treatment or discussion.

(*1*) *Size of towns included:* I think Mr. Watkin's range of populations from 500 to 2,000 well chosen at this time. Twenty years ago I would have said 1,500 to 3,000. At that time, nearly all cities in Kentucky of more than 3,000 had water systems of some sort, and quite a number of 2,000 to 3,000, also. New construction for the ten years following the World War was mostly confined to cities of 1,500 and over, and a great deal of such work was in the nature of improvements in pumping equipment and water purification for cities of from 1,500 to 10,000 population. With the demand for

better living conditions generally, the people of the smaller towns have found that water supplies are a necessity, in order to avoid the alternative in a few years of finding themselves communities of old people, with dwindling populations and business. Ten years ago it was scarcely considered practical for a town of less than 1,500 to finance and support a modern water supply, as reliance must be upon private capital. With the laws permitting fifth and sixth class cities to finance through revenues, the most of such towns of 1,000 to 2,000 population have found it practical to finance such works, and with the Federal Government grants and market for the revenue bonds, the range has been extended to towns as small as 500 population. It is my opinion that the next ten years will witness the extension of public water supplies to include a great many communities of less than 500,—possibly 150 to 500, where such communities are favorably situated as regards convenient and suitable supplies. The servicing of such small communities presents similar problems to those of servicing the larger ones, but engineers will have to provide equipment and construction of different types and capacities, in order to meet the financial requirements. Complying with underwriters' rules for grading will be out of the question. Also, purification equipment will, in most cases, require a shop built outfit designed for a minimum of erection cost. Electrification has already preceded water works in nearly all such towns, and power problems are thereby easily solved.

(*2*) *Mixing and coagulating device:* From my own experience, I have learned that mechanical mixing devices are usually too expensive to include in filter plants of less than 350 g.p.m. capacity, or one-half million gallons per 24 hours. For plants designed for populations of 1500, or less, we usually drop back to 250 g.p.m. as the rated plant capacity, as this is the minimum that is recognized by the Kentucky Actuarial Bureau for insurance grading. We sometimes even cut the plant capacity to 125 g.p.m., in order to get the cost within the funds available, with provision in the design for equipping with duplicate units in filters and pumps of same capacity. For plants of 250 g.p.m. capacity and under, our rule is to install a baffled type of shallow mixing chamber, designed to give a whirling motion to the water by reversing its direction in each bay or compartment. Such mixers are usually designed to give 15 to 20 minutes mixing and coagulating periods. Flexibility for the introduction of chemicals through rubber hose is provided by this arrangement, in

order that the point of application of each chemical may be changed to obtain the best results in coagulation. The use of timber baffles of cypress permits of further changes in baffle openings, and rearrangement for time of retention at small trouble and expense. These mixers have given good results and proved satisfactory. By placing over the settling basin, convenience of cleaning is accomplished.

For larger plants—350 g.p.m. and over—it is our practice to provide some form of mechanical flocculator. Up to 700 g.p.m., we have used one unit and above that, as a rule, two units. We also provide a by-pass between coagulating chamber and filter influent when settling basin is in one unit. We have customarily used a vertical type of mechanical flocculator, with paddles revolving about 3 r.p.m. Chemicals are introduced at the bottom and flocculated water taken from near the surface to the settling basin. This allows the operator an observation of the results of the coagulation as the water leaves the mixing chamber. A 1-h.p. electric motor with reduction gears is usually sufficient for a mixer of this type. Various air mixing devices are also available for this purpose and have proved effective although usually higher in cost. One of these devices is now being put in operation in the new filter plant at Lebanon, Kentucky. Very effective devices in mechanical flocculators, with horizontal paddles set in fairly shallow basins, or in sections of settling basins, are also being used. While equally effective in properly designed mixers for new plants, these have the advantage of being adaptable to installation in the first bays of around-the-end settling basins. A device of this nature is now being installed at the Lexington Water Works.

As regards Mr. Watkins' time of 30 to 60 minutes for coagulation, will say that in my own experience, this is longer than necessary for most waters. We have usually considered from 10 to 20 minutes sufficient for the optimum production of floc. In one case, that of Jackson, Ky., with a very soft water we found that, with the use of lime and alum, we had to cut the time after introduction of the alum to about 10 minutes by applying it at a point about one-third of the distance of travel through the basin.

(3) *Sedimentation basins:* Probably the greatest departure from conventional designs in construction of small water plants is in that of the sedimentation basin. For best results, a settling period of from 5 to 6 hours should be provided. However, the funds available usually determine its proportions. With small towns there is

the factor of time of daily operation which enters into the problem. For instance, a town of 1,000 population, using 30,000 gallons per day, with a 250 g.p.m. plant, will require pumping only two hours per day. With a 3 hr. basin, giving ample allowance for dead spaces, it will be seen that the treated water will not pass through the plant and to the customers on same day it is treated. Therefore 24 hrs. sedimentation, mostly in a still condition, results. For such conditions, we prefer a deep, "down-and-up" circular type of settling basin. To avoid excessive cost of excavation, and proper drainage facilities, however, this type is most adaptable to hillside construction. A single cone shaped cell can be made of the bottom, which facilitates cleaning of the sludge, which can be done from a bridge above by means of a garden hose. This type of basin can also be used for storage of treated water, by building above the tops of the filters and controlling flow to filters by a float valve. This system is best for use with a well supply, where iron or other sediment, as from a cave supply, are to be removed, and the deep well pumps are of smaller capacity than the filters and high pressure pumps. This system also required placing of the chemical feed at a high elevation, or the pumping of chemicals.

As regards the materials for construction of settling basins, we have found steel the most suitable where a circular basin is practical. It is also usually the cheapest construction. As covering such basins is expensive, and interferes with observation of their performance and cleaning, the action of ice and frost on concrete usually results in its rather rapid deterioration unless it can be banked with earth to near the top and ice kept broken up during severe cold spells. The results of temperature stresses are not so bad in circular basins, but we have found that all rectangular ones not banked will develop vertical or diagonal cracks from extremes of weather conditions. These may not become apparent for several years, or until a very severe winter is encountered. By careful workmanship water-tight concrete can be produced, but these cracks will in time allow slight seepage and frost action. If a circular basin is provided, there is not much danger of vertical cracks provided ice pressure is not allowed to develop. However, in case a mixing chamber is placed in a circular concrete basin, it should be supported in such a manner as not to interfere with the free expansion and contraction of the outer basin wall. Use of slag, or other porous materials, should be avoided. Tight walls may be obtained with these materials, but the water will

finally fill the voids and wait for a severe cold spell to burst, spall, and disintegrate the concrete. We mention here a case of our own experience, where plant was built in 1921. Gunite was used in 1935 to restore beams and copings where slag was used. Also in rectangular basins, with walls over 30 feet in length, construction joints with metal cutoffs inserted and grooved joints should be provided at predesigned places, not over 30 feet apart, in order that cracks may not develop and nature make joints without provision for making them watertight. Reinforcement may be continuous through such joints. We are still experimenting, however, and have yet to build the exposed rectangular concrete basin that will not crack from extremes of temperature at or near the corners. Steel basins may be made with concrete floors and footing. A bituminous joint of materials suitable for sewer pipe jointing has been successful in producing a water tight joint. Concrete is more adaptable for making a floor that can be cleaned of sludge.

(4) *Filter wash:* For washing filters, our preference is the use of a wash water tank at sufficient elevation to give an average static head on wash troughs of 23 feet, or 10 pounds, in case tank is immediately above the building and connected by suitable piping. Where tank is on tower outside building with a longer line and extra bends, static heads as high as 30 feet may be required. These heads will net approximately the same as those given by Mr. Watkins for heads at the strainers. In small plants, where highly trained operators and scientifically educated supervisors are not available, it is best to provide simple equipment, made for a certain limited range of performance, without provision for very fine adjustments, or precision in operation. A wash water tank more nearly meets these requirements than any other method of filter wash.

For plants as large as 500 g.p.m., with sufficient clear well capacity and electric power, a wash water pump probably presents the most economical method. For smaller plants, with clear well omitted, the wash pump is not practical. Washing from high pressure tank through the city mains is accompanied with some danger of bursting mains from too quick closing of valve, and also tends to stir up sediment in pipes and otherwise interfere with the service. However, this offers the cheapest method where elevated tank is near enough to give the required flow. Where such tank is between plant and city, we have customarily used this method.

The most convenient, economical and aesthetic mounting for

wash water tanks has been one of our recent problems. Placing over the roof of the building a steel tank of from 8,000 to 10,000 gallon capacity for a 250 g.p.m. plant in two filter units, seems the most economical. At least, the lowest bids have been received on this setting. In such cases, these tanks have been mounted on steel beams supported by plastered walls of the building. In one case, we have mounted tank 10 feet diameter by 16 feet height on flat roof of building without any ornamentation of the setting. In another, we have planned to enclose the tank in a brick tower, open at the top. This one is to be located on the Court House Square, where appearances must be considered. In another case, we made a cupola, with dome effect, by mounting the tank over an octagon brick and concrete base on the roof of building. The tank has an hemispherical top. In another case, the tank is mounted horizontally across the plant walls and supported by a cradle consisting of two I-beams, with three curved supports for tank, all supported on the brick walls. This latter is the most economical method, while that with the tank forming a cupola, is in my opinion, the best looking.

Normal filter wash requires about 3½ minutes. Two filters, therefore, require water for at least 7 minutes wash at standard rates of washing. Two filters with 70 square feet area each require about 1,000 g.p.m. for washing 7 minutes, or 7,000 gallons. For extremes of washing time, it is better to provide a tank of 10,000 gallons, or sufficient for two five-minute filter washes.

In the matter of the provision for horizontal washing of the filter sand at same time as the main flow of wash water is through the strainers and in an upward direction, we understand that some improvements along this line are taking place. However, the high rate wash has served pretty well, with but little outside help, for thirty years. The inventor and developer of this system, has lately re-entered the field with a device for horizontal surface washing combined with the additional function of introducing the treated water below the top of the sand bed, thus increasing the capacity of the filters. This seems to present possibilities for increasing the capacity of old plants at much less cost than building extensions.

(*5*) *Intakes:* As river intakes are usually the source of more trouble than all other features of a small water plant put together, I think it well to mention briefly some of the devices used for taking water from large streams. Where extreme range between high and

low water occurs, the cost of water tight pump pits is often prohibitive in the case of a small plant. I think in some cases a raft supporting the raw water pump, with automatic priming device, and connected with shore piping by rubber hose, would prove the most satisfactory solution, although the underwriters say "NO." A duplicate raft and pump could be maintained on the river bank, ready for launching in case the one in use is lost, and with little expense. Every situation, however, presents a problem all its own. In some cases submersible motor pumps fit the situation. We advised the use of such a pump three years ago by one of our clients who was building a filter plant on a river bank in West Virginia, with intake in low ground about 500 feet distant. We believe this was the first installation of this kind of pump for a river intake. They naturally had some difficulties. I understand these have since been corrected, and that the pump is now giving satisfactory service.

We have lately installed a movable pumping outfit for an Ohio river town. This is not a new idea, but the conditions required some rather unusual features. An electric centrifugal pump is mounted on a carriage similar to those used for contractors' pumping units. A steel housing, lined with Celotex, encloses the pump motor and Apco primer. An oil stove hung from the ceiling furnishes heat. The truck runs on a 6 inch steel channel track on concrete piers in river bank, and is adjusted by a windlass. A rubber hose with aluminum strainer provides suction, and similar hose, all 4 inch size, connects to underground piping. This outfit is 1100 feet from main station on high river bank in the city and is supplied with current through an underground lead covered conductor laid in conduit. The controls are in the main station. During high water periods this outfit is hauled over the road adjacent to town and service taken care of by a similar device in the city at the main plant. This second outfit also serves as a duplicate unit in case the main river outfit is down.

WATER SUPPLY IMPROVEMENTS NEEDED IN INDIANA*

By P. C. Laux† and R. B. Wiley‡

There are 292 water supplies in Indiana ranging in size from the large properties of the Indianapolis Water Company to a dug well supplying twelve people. The quality of the water varies from the thoroughly purified and softened product furnished at Fort Wayne, Lebanon and Crown Point to the raw river water pumped into the mains at Vevay and Hazleton.

The number of supplies, population served and sources are shown in table 1.

In all cases where there are dual supplies, such as surface and well supplies in the same town, the system was classified under that source furnishing the major portion of the water.

Of the total 231 (79%) are for towns of less than 5,000 population and 235 (81%) are well supplies. Two hundred and nineteen (75%) are tubular well supplies and 73 (25%) are surface water, dug well, infiltration gallery and spring supplies. The latter sources are particularly susceptible to pollution.

Table 2 shows the methods of treatment in use.

Under the heading "Purification" are included all surface supplies with treatment other than chlorination. Two supplies and part of another in this group are coagulated, settled and chlorinated but not filtered.

The most startling fact brought out by this table is that 166 or 57 per cent of all the supplies in the state are entirely untreated. Four percent of the surface supplies, 37 percent of the dug well supplies, 71 percent of the tubular well supplies and 43 percent of the spring supplies have no treatment whatever.

* Presented before the Indiana Section, March, 1937.

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TABLE 1

Number and sources of water supplies in Indiana

NUMBER OF SUPPLIES	POPULATION	SURFACE	DUG WELLS	TUBULAR WELLS	INFILTRATION GALLERIES	SPRINGS
105 } 231	Below 1,000	6 } 21	5 } 202	{ 89	1 } 8	{ 4
126	1,000– 5,000	15	9	99	1	2
27	5,000– 10,000	8	1	18	0	0
16	10,000– 20,000	5	1	9	0	1
10	20,000– 50,000	5	0	3	2	0
3	50,000–100,000	3	0	0	0	0
5	Over 100,000	4	0	1	0	0
292	Totals	46	16	219	4	7
Totals..................		46		235	11	

TABLE 2

Methods of treatment used for various water supplies in Indiana

NUMBER OF SUPPLIES	TYPE OF SUPPLY	PURIFICATION	SOFTENING	IRON AND CO_2 REMOVAL	CHLORINATION ONLY	NO TREATMENT
46	Surface	38	1	0	5	2
16	Dug wells	0	0	1	9	6
219	Tubular wells	0	2	6	56	155
4	Infiltration gallery	0	0	0	4	0
7	Springs	0	0	0	4	3
292	Totals	38	3	7*	78	166†

* 6 also chlorinated.

† 167 unchlorinated.

In table 3 the surface supplies of the state are classified into three groups as to hardness:

1. Soft (or softened), 8 grains per gallon or less
2. Moderately hard, 8 to 15 grains per gallon
3. Hard, more than 15 grains per gallon

They are also classified into three groups as to purification:

1. Purified
2. Chlorinated only
3. Untreated

It will be noted that two surface supplies are entirely untreated (not even chlorinated), five are chlorinated only, two are coagulated and settled but unfiltered, and one is partly unfiltered. Twenty-five (54%) of the 46 surface supplies are hard when delivered to the consumer.

TABLE 3

Grades of hardness and methods of treatment of surface supplies in Indiana

NUMBER OF SUPPLIES	POPULATION	SOFT	MODERATELY HARD	HARD	PURIFIED	CHLORINATED ONLY	UNTREATED
6	Below 1,000	4	0	2	3	2	1
15	1,000– 5,000	4	2	9	12*	2	1
8	5,000– 10,000	2	1	5	8	0	0
5	10,000– 20,000	1	0	4	5†	0	0
5	20,000– 50,000	2	0	3	5	0	0
3	50,000–100,000	2	0	1	3	0	0
4	Over 100,000	3	0	1	3	1	0
46	Totals	18	3	25	39	5	2

* Two supplies unfiltered.
† Part of one supply unfiltered.

TABLE 4

Methods of treatment of tubular well water supplies in Indiana

NUMBER OF SUPPLIES	POPULATION	CHLORINATED	UNCHLORINATED	IRON REMOVAL	SOFTENED
89	Below 1,000	12	77	0	0
99	1,000– 5,000	24	75	2	1
18	5,000– 10,000	11	7	0	1
9	10,000– 20,000	6	3	1	0
3	20,000– 50,000	2	1	2	0
0	50,000–100,000	0	0	0	0
1	Over 100,000	1	0	0	0
219	Totals	56	163	5	2

In table 4 the tubular well supplies are classified as to methods of treatment.

Of all these (219) well supplies only 56 or 26 percent are chlorinated, five are treated for iron and carbon dioxide removal and two are softened.

Eighty-one percent of all the tubular well supplies in towns of less than 5000 population and thirty-six percent of those supplies of more than 5000 population are unchlorinated.

Only five plants provide for iron removal and two for softening, yet the need for this type of treatment is shown in table 5.

TABLE 5

Average mineral analysis of tubular well waters in Indiana

	PARTS PER MILLION		
	Maximum	Minimum	Average
Alkalinity	520	88	300
Hardness	566	60	331
Iron	12	0	1.25
Carbon dioxide	50	2	15
Chlorides	300	2	16
pH value	8.1	6.8	7.4

TABLE 6

Classification of dug well supplies in Indiana

NUMBER OF SUPPLIES	POPULATION	CHLORINATED		HARDNESS DEGREE			IRON CONTENT		
		Yes	No	Soft	Medium hard	Hard	High	Medium	Low
5	Below 1,000	3	2	0	2	3	0	2	3
9	1,000- 5,000	7	2	0	3	6	1	1	7
1	5,000-10,000	0	1	0	1	0	0	0	1
1	10,000-20,000	1	0	0	0	1	1*	0	0
16	Totals	11	5	0	6	10	2	3	11

* Iron removal plant in operation.

Soft—8 gr. per gal. or less. Medium hard—8 to 15 gr. per gal. Hard—Over 15 gr. per gal. High iron—Over 1 part per mill. Medium—0.5 to 1 part per mill. Low—0 to 0.4 part per mill.

Not only is the average well supply hard and high in iron but, according to the pH value and the carbon dioxide content, it is corrosive. The high chloride content may indicate sewage seepage.

Table 6 for dug well supplies shows only two in use in cities of over 5,000 population.

Two supplies are treated for iron removal and only 69 percent are chlorinated.

Eleven supplies come from infiltration galleries or springs. The four infiltration gallery supplies and four of the seven spring supplies are chlorinated. It is assumed that filtration is unnecessary but undoubtedly softening would effect considerable saving as four supplies are very hard.

The bacterial quality of many water supplies leaves much to be desired. The State Division of Public Health lists six supplies as being unsafe and sixteen as being of questionable quality. One of these twenty-two supplies is included because of the high flouride content. All others are included because of poor bacterial quality. With 167 unchlorinated supplies in the state we are fortunate that the number of unsafe supplies is not larger.

The unsafe supplies can be classified as follows:

1. Two untreated river supplies.
2. Four limestone supplies,
   (a) Two unchlorinated.
   (b) Two improperly chlorinated.

The questionable supplies can be classified as follows:

1. Thirteen deep well supplies,
   (a) Ten unchlorinated.
   (b) Three chlorinated.
2. Two impounding reservoir supplies,
   (a) One chlorinated only.
   (b) One coagulated, settled and chlorinated but unfiltered.

Water supply improvements needed in Indiana are:

1. More universal chlorination, especially of well supplies ordinarily considered safe. Certainly stand-by chlorination for emergencies is a direct obligation to protect public health.
2. More careful attention to proper chlorination practices.
3. More complete purification of surface and high ground water supplies.
4. Iron and carbon dioxide removal for many well supplies.
5. More general practice of water softening for all types of water supplies.

Those in charge of our water supply systems are not dealing fairly with their customers if they do not take account, after a careful study, of the economies to be effected by softening and iron and carbon dioxide removal.

"THE USE OF INHIBITORS IN ACID SOLUTIONS EMPLOYED TO CLEAN WATER PIPES"*

By A. R. Hollett

(Department of Civil Engineering, University of North Carolina; City Engineer, Chapel Hill, North Carolina)

Corrosion could probably be called the public enemy No. 1 in the water works field, and unfortunately, is still at large in most sections of the country. It has been conservatively estimated that corrosion alone costs the taxpayers of New York City from four to ten million dollars annually.

There are two different phases to the corrosion problem. First, the prevention of corrosion, which has been so ably covered in the various journals and publications, and second, the removal of accumulated corrosion products. This brief paper will deal only with the second phase of the problem.

Frequent examples have been cited where ninety to ninety-five percent of the original carrying capacity of pipes has been restored by mechanical scrapers, but frequently the pipe linings were injured during the cleaning operation and rapid corrosion and tuberculation followed. This method of removing corrosion materials cannot be applied to small pipes and services and in many cases expensive replacements have been necessary, involving the cost of replacing walls and floors. As a result numerous attempts have been made to remove the accumulated materials with acid, which were in most cases unsatisfactory as the scale was variable in thickness and the time of contact could not be regulated to prevent the acid from attacking the walls of the pipe.

The steel industry has for many years made use of a process called "pickling," which is the removal of scale by immersion in an acid. It was found that the addition of certain organic materials, such as aniline, pyridine, quinoline, quinoline ethiodide, certain cold tar products, and even bran, flour and glue, greatly decreased the destruction of clean metal and yet permitted the solution of the scale. Such materials have been called "inhibitors."

* Presented before the North Carolina Section, November, 1935.

THEORY OF INHIBITORS

The action of inhibitors has been known for many years but has been given very little theoretical consideration. Chappell, Roetheli and McCarthy (1) made a detailed study of inhibitors in 1927. Apparently the following two reactions occur in the pickling bath:

(1) $FeO + H_2SO_4 \rightarrow FeSO_4 + H_2O$
(2) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

Equation 2 would be expressed electrochemically as follows:

(3) Anode $- Fe^{++} + 2\,\theta$
(4) Cathode $- 2H^{+} + 2\,\theta \rightarrow H_2$

It was observed that reaction (2) proceeded slowly in the presence of an inhibitor, so the investigators concluded that probably the inhibitor interferred with both reactions (3) and (4) and decided to study each separately. Although too expensive for commercial use, quinoline ethiodide, a material of known composition, was chosen as the inhibitor. They carefully studied (1) the rate of hydrogen evolution (equivalent to metal consumption) with a normal sulphuric acid at 60°C. and in acid containing varying quantities of the inhibitor; (2) its effect on the reactions at the cathode and anode and (3) the action of other inhibitors in order to test the general applicability of the relations found in (1) and (2). On a basis of these studies the investigators advanced the following theory:

> "When immersed in an acid, iron goes into solution at the anode areas, forming ions and discharging hydrogen ions at the cathode areas. These cathode areas may be said to occur principally in the narrow spaces of the grain boundaries in steel or between the metal and slag in wrought iron. Most inhibitors are either bases such as quinoline, or positively charged colloids, and when these are present they travel to the cathode areas with the hydrogen. When the positively charged heavy particles are discharged, they cannot escape by gaseous evolution, and accordingly are absorbed on the surface, building up a protective layer."

SELECTION OF INHIBITOR

It was found that the chemical condition or properties of a compound and its effectiveness as an inhibitor are not related. Speller

and Chappell (2) verified this statement by measuring the hydrogen evolution from steel in 34 percent sulphuric acid at 25°C. These investigators also found that the initial addition of an inhibitor made enormous reductions in hydrogen evolution, while higher concentrations of the same inhibitor further reduced the hydrogen evolution but were uneconomical when working time and cost were taken into consideration. Chappell and Ely (3) made a similar study on a large group of commercial inhibitors. The latter group of materials, although quite effective as inhibitors, are, in many cases uneconomical as the sales expense results in high prices.

It is quite evident that each material should be carefully studied in the laboratory for its effectiveness as an inhibitor, based on hydrogen evolution from a standard sample, under the conditions of temperature, concentration of acid, etc., which it would be used in the plant.

APPLICATION TO THE WATER WORKS FIELD

Inhibitors in acid solutions have been successfully used in many instances for the removal of corrosion products from small pipes (maximum diameter of 4 inches). Apparently no attempt has been made to remove corrosion products from the large mains of the distribution system by this method.

Speller, Chappell and Russell (4) described the initial method of application of rust removal from a piping system with acid, to which had been added an inhibitor. A 35 story office building in downtown New York, occupied by tenants of the highest class, was the immediate occasion for the development of this cleaning method. Corrosion products had so diminished the carrying capacity of the piping system that immediate correction was necessary. Most of the pipes were behind marble walls and replacement would have been prohibitive. Estimates indicated that the replacements would have cost between $100,000 and $300,000.

The section of piping to be cleaned was cut off, drained and filled with rust solvent, a strong hot solution of hydrochloric acid to which had been added an inhibitor. The strength was so chosen as to dissolve the corrosion materials in five to six hours. As the solvent was used up, it was necessary to renew the material immediately or the rust would merely be loosened resulting in serious stoppages. At the end of the contact period the solvent was removed and the pipes thoroughly flushed with clean water. The cleaning operations were

carried out on Saturday afternoons in order not to interfere with the tenants. Seven week ends were required to complete the work.

Abrams and Wagner (5) made a series of tests on galvanized iron pipes to determine the effectiveness of inhibitors in preventing the action of acid on the metal. In parallel tests 16 percent muriatic acid was used alone, to compare with the same acid with 3 percent of an inhibitor. At the end of six hours contact the pipe in acid had lost 50 percent of its weight, while that in the inhibited acid lost only 0.2 percent of its weight. These investigators were almost immediately given an opportunity to apply their findings in practice, as two lengths of pipe leading from the basement to the second floor of their office became completely filled with rust. The pipes were opened at the top and an inhibited acid poured in, allowing it to work its way downward. One overnight treatment, followed by complete flushing of the pipes restored them to their original carrying capacity.

Abrams and Wagner (5) also reported the cleaning of the piping system in the Mount View Sanatorium, Marathon County, Wisconsin. Twenty-five gallons of 14 percent muriatic acid, containing 3 percent by volume of an inhibitor, was pumped upward through a 1-inch pipe, through a cross-over and down another length of pipe to the basement. Due to dislodged material in the pipes, it became practically impossible to force the acid through the system. The system was finally closed and filled by gravity with solvent, allowing it to remain for eight hours, after which the acid was removed and the pipes thoroughly flushed. In order to determine the effectiveness of the cleaning operation, three 6-inch lengths were cut from a 1-inch pipe whose opening had been reduced to the size of a lead pencil. Two of the sections were reinserted in the system, one of which was removed after a two-hour contact with the acid, and the other removed at the end of ten hours. The first section removed showed that it was practically clean, excepting a few rust patches, while the second section was entirely free from corrosion materials with no apparent action on the metal by the solvent. Approximately 2800 feet of pipe ranging in diameter from ½ to 4 inches was cleaned at a cost of $870 for labor and $20 for acid. It was estimated that it would have cost $8,500 to replace the above piping.

SUMMARY

It is quite evident that metallic pipes can be inexpensively cleaned of accumulated corrosion products without damage to the metal

surface by the use of inhibitors in acid solutions. The inhibitor, its concentration, working temperature, etc., should be carefully studied in the laboratory before being used in the piping system. Although the method has not been applied to the larger pipes in the distribution system, it is felt that such application is not at all impractical and offers an excellent field for research.

BIBLIOGRAPHY

(1) CHAPPELL, E. L., ROETHELI, B. E., and McCARTHY, B. Y. The Electro-chemical Action of Inhibitors in the Acid Solution of Iron and Steel. Ind. and Eng. Chem., 20, 582 (1928).

(2) SPELLER, F. N. and CHAPPELL, E. L. Inhibitors—Their Behavior in Laboratory and Plant. Am. Inst. Chem. Eng., 19, 153 (1927).

(3) CHAPPELL, E. L. and ELY, P. C. The Pickling of Pipe Using Commercial Inhibitors. Ind. and Eng. Chem., 22, 1201 (1930).

(4) SPELLER, F. N., CHAPPELL, E. L., and RUSSELL, R. P. Removal of Rust from Pipe Systems by an Acid Solvent. Am. Inst. Chem. Eng., 19, 165 (1927).

(5) ABRAMS, ALLEN and WAGNER, C. L. Use of Inhibitors in Cleaning Metallic Pipe. W. Wks. and Sew., 82, 192 (1935).

A STUDY OF CHEMICALS USED FOR CLEANING RAPID SAND FILTERS*

By John C. Geyer† and H. L. Chang‡

In many filter plants serious difficulties arise from the gradual formation of a plastic, clay-like coating on the sand grains. If the growth of this coating is permitted to continue, large filter cracks will develop toward the end of each run, and mud-balls will form in the filters which are not disintegrated by backwashing. If the conditions are not remedied, the mud-balls will grow in size and gradually move to the bottom of the filter where they form clogged areas in the bed. The filter must then be taken out of operation and the sand removed and cleaned.

Various mechanical means have been used in attempts to prevent the formation of large mud-balls. High rate washing has received considerable attention and is now quite generally recommended, various rakes and tools have been used for breaking up or removing the mud-balls during the backwashing operation, and the use of an auxiliary surface wash has been advocated. These measures, however, have not been found practical or have not been found completely effective in many cases, and the filter operator has had to resort to the use of chemical treatment to remove the dirt from the sand grains.

A study of available literature indicates that one of the earliest applications of chemical treatment was at the Montclair filters, Little Falls, N. J. in 1924 (10). Since that time, various chemicals have been tried in many filter plants. The degree of success in removing the sand grain coatings has varied. Some of the chemical treatments which have been reported are outlined in table 1. Caustic soda seems to be the most frequently used chemical although sulphuric

* Presented before the North Carolina Section, October, 1936.

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acid (3), hydrochloric acid (16) and other chemicals have been employed to some extent.

Apparently, these chemical treatments have been selected somewhat arbitrarily and have been applied in the manner which the particular operator judged most suitable. Since the use of chemicals for cleaning the sand bed is periodically necessary in some plants, the desirability of obtaining more detailed information concerning their use is evident.

The operator should know beforehand just what is required of the chemical treatment and should be able to select that particular treatment which will produce the desired results. In general, an ideal treatment would be one which is cheap, foolproof and rapid in action, one that would not damage the filter box or the underdrains, and one that can be applied as frequently as is necessary to prevent the formation of mud-balls or the occurrence of other undesirable conditions in the filter bed. The tests reported here were undertaken to obtain information which might be of use in working out such a desirable treatment.

The specific objectives of the study were as follows:

(1) to compare the cleaning efficiency of various chemicals;
(2) to determine the most suitable strength of chemical solution and the required period of contact with the sand to produce best results; and,
(3) to investigate the best method of applying the chemical solution on the sand bed.

In order to conduct this study, it was necessary to develop a laboratory procedure by which the effectiveness of the various chemicals could be tested.

TEST FOR COMPARISON OF EFFICIENCY OF CHEMICALS

In developing a test for comparing the efficiency of the chemicals which might be used to clean the sand, it was necessary to develop some means for determining the amount of dirt removed without first drying and weighing the sand. It was thought that drying the dirty sand before applying the chemical might not produce results which would be comparable with the cleaning obtained by applying the same chemical solution to a wet sand bed. In order to overcome this difficulty, the sand was treated with the chemical before drying, then washed, dried and weighed. A secondary treatment which removed the balance of the dirt was applied and the sand was again

TABLE 1

Chemical cleaning of rapid sand filter beds in different plants

PLACE	CHEMICAL USED	QUANTITY	METHOD OF APPLICATION	TIME OF TREATMENT, HOURS	RESULTS	BIBLIOGRAPHY REFERENCE
Little Falls, N. J.	Caustic Soda & Soda Ash	NaOH 1.8 #/sq. ft. Soda Ash 5.2 #/sq. ft.	1″ water above sand. Solution made up separately. Live steam used to heat tank contents just below boiling point for 48 hours	48	Organic material and aluminum hydrate removed. Sand as clean and sharp as new	6
Monroe, La.	Caustic Soda	0.83 #/sq. ft.	4″ water above sand. Chemical added. Stand 6 hours. Rake every 3 hours for 15. Draw water level to sand surface and stand 6 hours. Wash to normal alk.	27	Good when alum used for coag. and sand high in organic matter	17
Monroe, La.	Hydrochloric Acid	10% by vol.	Not described		Good where iron and lime coag. or softening used. Effectively removes incrustation	17
Detroit, Mich.	Caustic Soda	0.8 #/sq. ft.	8″ water above sand. Chemical added. Water level drawn to 4″ on sand, held 24 hours. Water level drawn to sand surface and held additional 24 to 48 hrs.	48–72	Caustic not very efficient but made coating easier to remove by subsequent washing	7

Newburgh, N. Y.	Caustic Soda & Chlorine	NaOH 1% Cl_2 6 #/m.g.		24	Mud-balls reduced and sand cleaned	10
Statesville, N. C.	Caustic Soda	1.2 #/sq. ft.	6″ water above sand. Chemical added. Sand raked every 3 hrs. for 15. Water level lowered to sand surface and allowed to stand 8 hours	22	Runs doubled and turbidity no longer passed filters	3
Greenville, N. C.	Soda Ash	0.2 #/gal.		24–36	Filter runs increased 20%	3
High Point, N. C.	Sulphuric Acid	0.092 #/sq. ft.	20 lb. per bed. Water level at sand surface. Acid poured on and mixed into sand with a broom	4	Sand restored to good condition	3
Louisville, Ky.	Chlorine	10–12 #/m.g.			Coating and organic matter removed	11
Verona, Pa.	Chlorinated lime or Cl_2 gas	50 p.p.m.	Filter soaked 48 hrs. Washed slightly. Furrowed & dried 24 hrs. Then given special type of wash	48	Sand visibly cleaner and filter runs increased	14

washed, dried and weighed. By measuring the total dirt and taking differences it was possible to figure the percent removal for various concentrations and times of treatment for each chemical tested.

The procedure used was as follows: Sand samples were collected from the top six inches of one of the Chapel Hill filters just before the backwashing operation. Better results might have been obtained had the samples been collected after washing. This was not

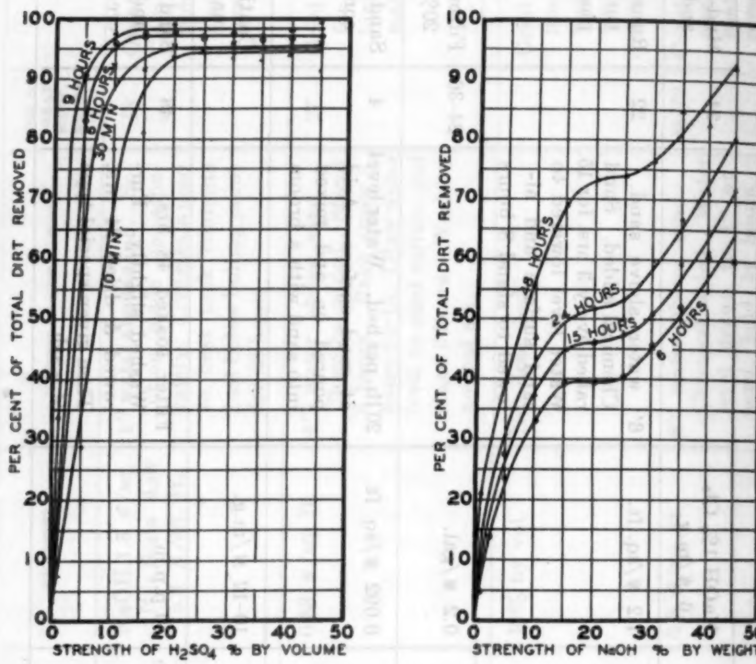

Fig. 1 Fig. 2

Fig. 1. Efficiency of Sulphuric Acid Solution in Cleaning Filter Sand

Fig. 2. Efficiency of Caustic Soda Solution in Cleaning Filter Sand

thought advisable because it necessitated frequent interference with the normal operation of the filters, and because the supply of wash water was not sufficient to give the filter the secondary wash required. The samples of unwashed sand were spread on a laboratory bench and mixed by turning gently until the distribution of mudballs and dirty sand was uniform. Portions containing approximately 200 grams of sand, on a dry basis, were placed in 600 ml. weighed beakers. One hundred milliliters of the chemical solution were

added and mixed gently into the sand. In a series of tests using different concentrations and a fixed time of treatment, five minutes were allowed between the dosing of successive samples to provide time for washing at the end of the treatment period. One portion, to be used for measurement of the total amount of dirt, was not treated chemically before the first washing and drying. At the end of the time each sample was washed by the standard method de-

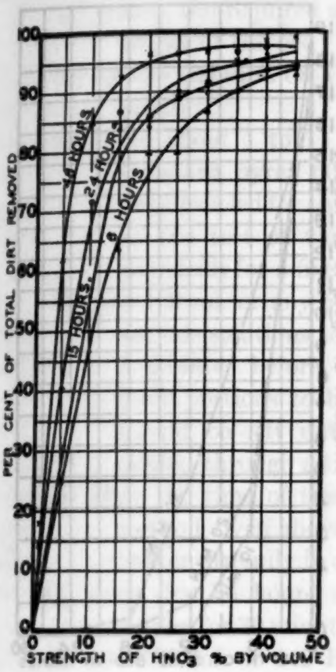

FIG. 3

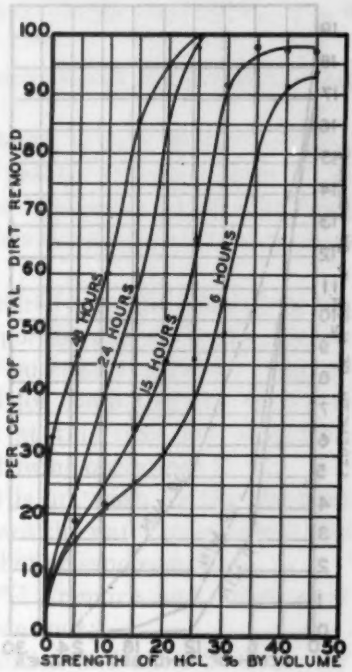

FIG. 4

FIG. 3. EFFICIENCY OF NITRIC ACID SOLUTION IN CLEANING FILTER SAND

FIG. 4. EFFICIENCY OF HYDROCHLORIC ACID SOLUTION IN CLEANING FILTER SAND

scribed below, then oven-dried for 36 hours at 120°C., cooled for 30 minutes to one hour and weighed. A standard treatment with 1:3 HCl was then given each portion to remove the balance of the dirt and each portion was again given the standard wash and again dried and weighed.

The 1:3 HCl treatment for 24 hours was selected as a standard for comparisons after tests had demonstrated that at least 96 percent

removal of the dirt was obtained by this treatment. Experience indicates that the use of a 1:2 HCl treatment for 24 hours, using 200 ml. of solution per beaker, would be a more satisfactory secondary treatment.

The apparatus used for the standard washing operation consisted of a carbon filter tube 3½ cm. in diameter into which was fitted a

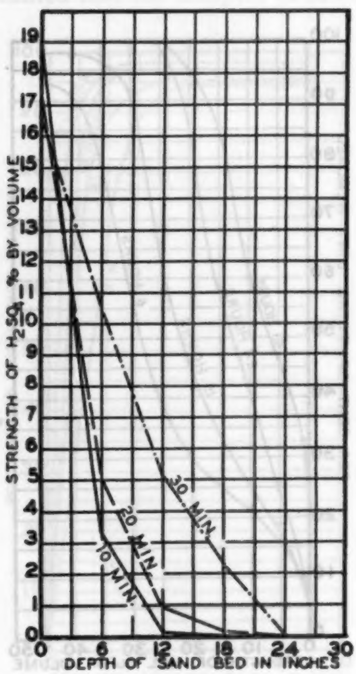

Fig. 5

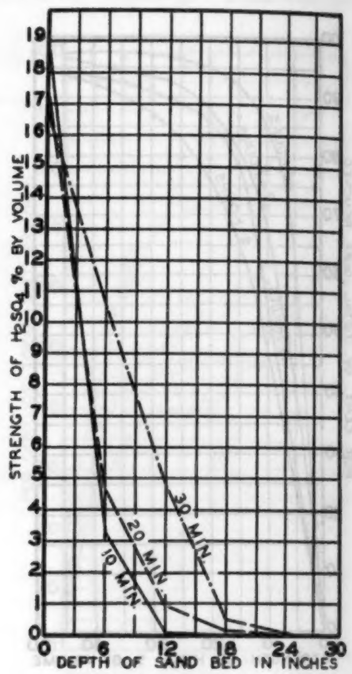

Fig. 6

Fig. 5. Penetration of Sulphuric Acid Solution into the Sand Bed at Center of Filter

Fig. 6. Penetration of Sulphuric Acid Solution into the Sand Bed Near Wall of Filter

rubber stopper which held 5 glass tubes 4 mm. in diameter. The center tube was straight. The four outside tubes had offset bends which provided a spacing of 2½ cm. from the center tube. The length of the tubes was such that the funnel was well above the beaker during washing. The apparatus was connected to a tap by a rubber tube and the 5 small glass tubes were inserted to the bottom of the

sand in the beaker. A washing rate which gave 30 per cent expansion of the sand was applied for four minutes. Approximately 9 liters of water were used for each washing.

In the light of experience gained in the use of this comparative test the following improved technic is suggested:

(1) backwash the filter and draw the water level below the sand surface;

(2) collect the required amount of sample from the top 2 to 6 inches of the bed;

(3) spread the sand on a laboratory bench and mix by turning gently;

(4) place about 1 to $1\frac{1}{4}$ inch depth of sand in each weighed standard pyrex 600 ml. beaker; (Equalize level in all beakers used for one series. One series is here considered as the test of various concentrations of one or more chemicals for a fixed time.);

(5) add 100 ml. or any other desired constant quantity of the various solutions to each portion and stir gently; (Allow 5 minutes before dosing successive portions. One or more portions to be used for computing the total dirt should be left untreated at this time but should be carried through all the following operations.);

(6) after the time of treatment is up, wash by the standard method given above (Decant the water remaining in the beaker carefully in order that no sand escape.);

(7) oven dry 36 hours at 120°C.; remove and weigh after cooling for 30 minutes to one hour;

(8) add 200 ml. of 1:2 HCl solution and allow 24 hours for removal of the remaining dirt;

(9) apply standard wash and decant;

(10) oven dry 36 hours at 120°C.; remove, cool for 30 minutes to one hour; dry; and weigh.

The computation of the efficiencies of the various chemical solutions may be made as follows:

W_1 = Weight of sample after treatment with the chemical to be tested.

W_2 = Weight of sample after secondary treatment with HCl to remove the balance of the dirt.

$P_1 = \dfrac{W_1 - W_2}{W_2} \times 100$ = Percent of dirt removed by secondary treatment with HCl solution.

W_A = Weight of portion used for measurement of the total dirt after standard wash and drying, only.

W_B = Weight of portion used for measuring the total dirt after standard treatment with HCl solution.

$P_2 = \frac{W_A - W_B}{W_B} \times 100$ = Percent of dirt removed from portions used for comparison, i.e., the total dirt expressed as a percent weight of the cleaned sand.

$\frac{P_2 - P_1}{P_2} \times 100$ = Percentage of dirt removed by any chemical solution in a certain time expressed in percentage by weight of the total dirt on the sand. This percentage is called the cleaning efficiency of the particular chemical solution for the time of treatment.

EXPERIMENTS ON EFFICIENCIES OF CHEMICAL SOLUTIONS

The cleaning efficiency of the following six chemicals was compared: caustic soda, sulphuric acid, hydrochloric acid, nitric acid, chlorinated lime, and soda ash. The strengths of solution used in each case were: 1, 5, 10, 15, 20, 25, 30, 35, 40, and 45 percent. The acid solutions were made from concentrated laboratory reagents in percentages by volume. The hydrochloric acid was 37 percent HCl, C.P. reagent; the sulphuric acid was 96 percent H_2SO_4, 66° Be., technical grade, and the nitric acid 70 percent HNO_3, C.P. reagent. The caustic soda solutions were made up in percentage by weight from C.P. grade pellets of the chemical.

Since the chlorinated lime and the soda ash were very inefficient, the results of tests using these chemicals will not be given.

Except for the sulphuric acid, the times of treatment for each strength of solution of each chemical were 6, 15, 24, and 48 hours. For the sulphuric acid solutions 10 minutes, 30 minutes, 6 hours and 9 hours treatment were tested.

Of six variable factors those held fairly constant were the amount of solution per unit of sand, the amount of dirt per unit of sand, and the composition of the dirt; while those varied were the kind of chemical, the strength of solution, and the time of treatment.

The results of the experiments are shown graphically in figures 1, 2, 3, and 4. When 80 percent or more of the dirt was removed the small mud-balls were fairly well broken up and the sand grains appeared

almost as clean and white as new. When 40 to 80 percent of the dirt was removed the treated sand consisted of both white and dirty grains, and when less than 40 percent of the dirt was removed the sand was not noticeably cleaned.

In order to remove 80 percent of the dirt, the curves show the following requirements for each chemical: caustic soda,—a 24 hour treatment with a 45 percent (by weight) solution; nitric acid,—a 6 hour treatment with a 23 percent solution; hydrochloric acid,—a 6 hour treatment with a 35 percent (by volume) solution; and sulphuric acid, —a 10 minute treatment with a 12 percent solution. Thus, a sulphuric acid solution of around 12 percent strength will clean the sand equally as well as solutions of other chemicals, two or more times that strength, left on the bed for much longer periods. These results at once suggest the use of a concentrated solution of sulfuric acid and a short period of contact for treatment of the sand bed.

Comparing the cleaning efficiencies on the basis of 6 hours treatment with 10 percent solutions of each chemical, the caustic soda will remove 33 percent of the dirt, the hydrochloric acid 20 percent, the nitric acid 47 percent, and the sulphuric acid 95 percent of the dirt.

These efficiencies apply to sand from the Chapel Hill filters. The Chapel Hill water is taken from a storage reservoir, aerated, treated with 1 to 1.5 grains per gallon of alum, settled and pre-chlorinated before filtration. The raw water, at times, carries considerable red clay in suspension. The total dirt on the sand used for these experiments varied between about 9 to 12 percent of the weight of the cleaned sand. The efficiencies of the various chemicals in cleaning sand coated with a greater or a less amount of dirt or through which a different type of water has been filtered might be quite different. However, analysis of sand grain coatings at various filter plants throughout the country have shown a marked similarity in composition of the coating material. The dirt removed from the Chapel Hill sand has not been analyzed. It is hoped that this can be done in connection with further studies of the problem.

In the application of these laboratory findings to full scale treatment, it might be expected that somewhat lower efficiencies would be obtained. However, there should be no wide differences in results if the strength of chemical in the bed is actually maintained at that used in the laboratory.

In order to determine the length of time which the concentrated chemical might remain in the top layers of the bed where cleaning

action is most needed, tests were made to measure the rate of penetration. These tests also furnished some information concerning the important question of danger to the underdrainage system.

RATE OF PENETRATION OF ACID

Since the cleaning efficiency of sulphuric acid was higher than that of the other chemicals, this acid was selected for making small scale penetration tests. The object of these experiments was to develop a method for applying the concentrated acid so that it would not penetrate to the underdrains during the time required for treatment. The experimental filter used was constructed of 24-inch corrugated culvert pipe, protected inside with two coats of asphalt aluminum paint and one coat of Inertol. This filter contained 30 inches of sand which had an effective size of 0.34 mm. and a uniformity coefficient of 1.837.

It was anticipated that the solution placed on the bed would lose strength rapidly by downward diffusion and mixing. For this reason, a treatment which would give an initial acid concentration of 20 percent in the top two or three inches of the sand was selected for these tests. Three methods of application were tried.

In the first method, the water was lowered to a depth of three inches above the sand surface and sufficient acid mixed into this water to produce a 20 percent concentration by volume. The solution was then drawn into the bed until the liquid surface stood just above the sand. At the end of 10, 20, and 30 minutes, samples were taken at depths of 6, 12, 18, 24 and 30 inches, near the center of the filter and at the wall. The samples were collected in small quantities if the first drop showed high concentration of acid. A few drops were wasted to flush the small collection tubes before taking each sample. These samples were then diluted and titrated with N/50 NaOH.

The solution penetrated rapidly into the sand bed. Although no acid had penetrated 30 inches at the end of 10 minutes, at the end of 30 minutes, an almost uniform concentration of 7 percent acid existed from top to bottom of the filter.

The second method tried was the same as the first except that the solution of acid was not drawn down into the bed. The acid penetrated at a much slower rate than in the first method, but it was still impossible to keep a high concentration in the top of the bed for as long as 10 minutes.

The third method of application was more successful than the first

two. In this method, the water level was drawn down to two inches below the sand surface and the solution was sprayed on the sand. The concentration of the acid solution used was 25 percent. It was computed that this solution would be diluted to 20 percent strength by the water held in the voids of the top two inches of the bed. Sufficient acid was used to bring the liquid level to the surface of the sand.

The acid penetrated much more slowly than when applied by either of the first two methods. Figures 5 and 6 show the concentration at various depths after 10, 20 and 30 minutes. No acid appeared at the bottom of the sand after 30 minutes. By this method, a higher concentration was maintained near the surface and the quantity of acid used was considerably reduced. It is likely, however, that the reduction in total quantity of solution used would result in less cleaning. The variations in amount of cleaning with total quantities of a given solution used were not investigated.

Spraying acid on the de-watered sand is similar to the method used for dosing laboratory samples. In the laboratory, it was found that some stirring of the sand was necessary to bring the acid in contact with all the grains. Presumably, then, in order to obtain best results in the filter, the sand should be stirred by raking or some similar means. The effect of raking upon the rate of penetration has not been studied. It would, no doubt, increase the downward mixing and diffusion of the acid.

For the third method, about 2 liters of 25 percent sulphuric acid solution are required per square foot of filter area. Figuring the acid at 4½ cents per pound in carboy lots, the cost of treatment would be 9 cents per square foot. If a filter rate of 125 million gallons per acre per day is used, the cost of the chemical for cleaning by this method would be about $31.00 per million gallons capacity. In large quantities, acid can be purchased at as low as $15.00 per ton, thus reducing the cost of the chemical to around $5.00 per million gallons capacity. The average amount of caustic that has been used at various filter plants is about one pound per square foot. Caustic soda costs in the vicinity of $2.50 per hundred pounds or $50.00 per ton. At this price the cost of NaOH treatment is about $8.70 per m.g. capacity. Although it is very difficult to give a generally applicable comparison of costs because of the variations in price with quantities purchased and because of the differences in freight charge, it may be concluded definitely from the above figures that

the cost of acid should be no more than for the common amounts of caustic used. Since the acid is much more efficient than the caustic soda, the cost for removing a unit quantity of dirt will be considerably less.

A record of the time required to wash the acid from the filters was kept for the second method of application. After the acid had remained in the filter for 60 minutes, the filter was washed at a rate which gave 30 percent expansion. The acidity of the wash water effluent dropped rapidly. At the end of 7 minutes, the water contained 150 p.p.m. acidity, and at the end of 13 minutes washing, the acidity of the effluent wash water was the same as the influent water.

DISCUSSION OF RESULTS

The above tests indicate that the following factors apparently make favorable the use of sulphuric acid for cleaning sand beds: (1) the cheapness of the treatment; (2) the fact that the cleaning action is sufficiently rapid that the beds would have to be out of service for not more than an hour during cleaning; (3) the completeness of removal of the sand grain coatings; and (4), the fact that the silica sand is not apt to be damaged by the acid as is the case when strong caustic solutions are used.

The unfavorable factors are: (1) the danger of corrosion should the strong acids reach the metal parts of the filter; (2) the danger of damage to the concrete filter box; and (3), the fact that the method has not been tried and proven successful by use in full size filters.

Regarding the first unfavorable factor, the small scale penetration tests indicate that with the proper method of application the acid will not reach the bottom of the sand layer during the period required to remove the grain coatings. However, the tendency for local heavier concentrations of the chemical to cause a turning over of the acid and water might cause much more rapid penetration in a large filter than in the two foot diameter filter which was used for the penetration tests. The use of acid should first be tried on a full scale under careful test conditions. Samples should be collected from various depths at several points in the bed during treatment and tested for acidity. If such tests indicated that the acid was penetrating downward into the sand more rapidly than had been anticipated, the filter bed could be backwashed immediately. Samples of sand taken before and after treatment might be examined to

determine whether or not the removal of dirt was the same as that obtained in the laboratory.

Full scale tests have not been made at Chapel Hill because the supply of wash water is inadequate to provide the 12 to 15 minutes washing required to remove the acid. In addition, the town depends on only two filters for its supply, and, should unlooked-for difficulties be encountered, the results might be more serious than in a larger plant.

The question of corrosion of the pipe underdrains and the concrete filter box is to receive further study. The use of inhibitors such as are now commonly employed for acid cleaning of mains are to be tried. The latter offer considerable promise of reducing danger to the iron portions of the filter provided they do not interfere seriously with the cleaning efficiency of the acid. Protection of the concrete by coating with an acid proof paint will probably be required before the strong solutions can safely be placed in the filter.

The tests indicate that there is no practical chemical treatment which will disintegrate the large mud-balls in a filter. However, the smaller mud-balls, 1 cm. or less in diameter, are fairly well broken up. The chemical treatment should be considered a preventive as well as a corrective measure and should be applied at intervals of sufficient frequency to avoid the formation of large accumulations of mud.

SUMMARY

A test has been developed by which the cleaning efficiencies of various chemicals may be compared with a fair degree of accuracy. Using this test, it was found that, of the chemicals compared, sulphuric acid was the most rapid in action and the most economical chemical for cleaning sand from the Chapel Hill filters.

Experiments with a two-foot diameter filter indicate that the penetration of acid into the bed takes place most slowly when the water level is drawn below the sand surface and the acid sprayed on the bed. The sand should be raked following application of the acid to break up mud-balls and to bring the chemical into contact with all the grains near the surface.

Further laboratory tests are needed to determine the value of various inhibitors which might be used with the acid to guard against corrosion of the underdrains. Means for protecting the concrete filter box from the acid need investigation.

And finally, full scale experiments are needed to demonstrate conclusively whether or not the use of strong acid solutions for short periods of contact is a practical method for cleaning filter sand.

BIBLIOGRAPHY

(1) Baylis, John R. "Cracks in Filter Beds." W. W. and Sew., 77, 37 (1930).

(2) Baylis, John R. "Filter Bed Clogging." W. W. and Sew., 77, 73 (1930).

(3) "Cleaning Filter Sand." (Round Table Discussion.) Journal, North Carolina Section, A. W. W. A. IX, 1, pp. 132–137 (Nov. 1931); 9-132 (1931).

(4) Gosnell, A. L. "Breaking up Mud-Balls in a Filter." W. W. and Sew., 76, 375 (1929).

(5) Graf, August V. "Reduction of Mud-Balls in Rapid Sand Filters." Eng. News-Rec., 90, 1031 (1926).

(6) Green, Frank W. "Caustic Soda and Soda Ash Solution for Filter Sand Wash." Jour. A. W. W. A., 12, 235 (1924).

(7) Hulbert, Roberts, and Herring, Frank. "Studies on the Washing of Rapid Sand Filters. Jour. A. W. W. A., 21, 1445 (1929).

(8) Hopkins, Edward S. "Cause and Prevention of Mud-Ball Formation in Rapid Sand Filters." W. W. Eng., 85, 1025 (1932).

(9) Herring, Frank W. "Filter Sand Maintenance." Jour. A. W. W. A., 25, 1234 (1933).

(10) Kingsley, John F. "Pre-chlorination of Filters." W. W. and Sew., 77, 194 (1930).

(11) Lovejoy, W. H. "Keeping Filter Sand and Gravel Clean." W. W. and Sew., 80, 180 (1933).

(12) "Mud-Balls in Sand Filters." W. W. Eng., 65, 513 (1926).

(13) Mahlie, W. S. "Composition of Mud-Balls." Jour. A. W. W. A., 14, 420.

(14) Priester, Max U. "Reconditioning Filters." W. W. and Sew., 81, 48 (1934).

(15) "Special Screen to Remove Mud-Balls from Mechanical Filters." Eng. News.-Rec., 78, 978 (1917).

(16) Ventre, Emil K. "A Practical Method of Cleaning Filter Sand." Jour. A. W. W. A., 21, 1523 (1929).

THE STREPTOCOCCI TEST FOR POLLUTION OF WATER*

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As early as 1898 Dr. A. C. Houston reported the great prevalence of streptococci in fecal matter. His results, checked in general by Clemsha (1) in India, indicate that coliform organisms and streptococci are present in feces in about equal numbers with the former slightly more numerous.

EARLIER STUDIES

Dr. Houston (2) stated that the addition of one part of excremental matter to one million parts of water should result in a concentration of streptococci of 17 per ml. In the examination of 52 weekly samples of Thames River water (1909) 13 samples contained streptococci in 1 ml. amounts. From these results he inferred that the Thames contained very much less than 1 part per million of *fresh* excremental matter.

Clemsha (1) found streptococci in only six 20 ml. portions out of 151 Indian raw waters examined. To Calcutta tap water he added an emulsion of feces and stored the mixture in quart cotton plugged bottles at 80°–85°F. In the nine experiments made, the initial concentration of coliform organisms ranged from 100 to 1000 per ml. and the concentration of streptococci ranged from 10 to 100 per ml. In 24 hours, streptococci were not found in two of the bottles. In 48 hours they were recovered in 20 ml. from three bottles and in 72 hours no streptococci could be found in any of them.

Houston (3) found streptococci, growing alone in sterile water, after as much as nine weeks storage at from 46° to 61°F., but in much reduced numbers. He concluded that their behavior in sterile water does not measure their vitality in the mixed biology of a natural river.

Clemsha (1) artificially infected a pond by spreading a mixture of

* Contributed review.

cow dung and human feces over the surface at sunset. In three days none could be recovered in 15 ml. amounts even from the bottom samples, where they persisted longer than at the top. He concluded, in agreement with Houston, that streptococci are numerous in fecal matter and live for a relatively short time in water. Therefore, he concluded, their presence in water indicates very recent pollution.

Houston, in his earlier work, spread the samples of water over Conradi Drigalski plates and picked all small colonies developing. Clemsha put the residue after centrifugalizing, into lactose broth and then onto Conradi Drigalski plates. Several sugars were used in an attempt to develop significant cultural characteristics. Lactose and salicin were fermented by almost all cultures isolated. However, cultural performance is of small value since the microscopic examination must be made.

HOUSTON'S REVISED METHOD

Houston (4) revised his method in 1930 to become a part of the *E. coli* determination. Initial incubation is in lactose peptone bile-salt medium at 37°C. for 24 hours. The cultures are shaken and two to four drops spread over the bottom of a sterile Petri dish. The dish is placed, with the lid raised, in a dry 37°C. incubator for 15 minutes and then transferred to an incubator with a humidity of 85 percent for about 45 minutes. The procedure must be followed exactly. Under these conditions, most of the *E. coli* perish. Melted agar is poured into the plate and moved back and forth a few seconds. Incubation is at 37°C. for 24 hours. The agar is removed with a sterile spatula and the colonies, which have grown on the underside, subcultured into lactose lemco peptone litmus broth and onto a fresh agar slant containing 0.1 percent sodium nitrate. Incubation is at 37°C. for 24 hours. Acid without gas in lactose broth, chains on the agar slant with no reduction of nitrates to nitrites identifies the culture as fecal streptococci. The presence of nitrite is shown by a darkening when a drop of metaphenylene diamine solution is placed on the culture. Other substances may be used (including raffinose and salicin) but are considered unnecessary.

In later work, (5) instead of drying the culture to eliminate most of the *E. coli*, 1 ml. of it is added to 10 ml. of sterile water and the mixture heated to 60°C. At the end of 10 and 20 minutes a few drops are spread over Drigalski Conradi plates. After 24 hours at

37°C. the colonies are subcultured as described above. It is recognized that the heating kills some of the weaker organisms and that the Drigalski Conradi medium is somewhat inhibitive.

In general, fecal streptococci may be distinguished from oral by the fact that the latter do not attack salicin and form weaker and smaller chains.

Dr. Houston reported a greater volume of work extending over a much longer time than any other investigator. He recognized the fact that the test cannot compete with the more delicate *E. coli* test but found it a valuable adjunct, as does Col. Harold (7), especially in suspected wells and springs. In filtered water streptococci may be present occasionally in 250 ml. but the manipulations become involved and the result in this volume is of doubtful significance.

MALLMAN'S STUDIES

Mallman (8) has found that the concentration of streptococci follows the bathing load in a small lake bathing area while total and coli-aerogenes group counts do not in some cases. The streptococci disappear over night and are not found in the sand on the bottom. Coli-aerogenes group and total count sometimes increase over night but usually are lower. He finds that, though streptococci are less resistant than the coli aerogenes group to exposure in bathing pool water, the latter is more susceptible to chlorine (9). Thus the coli-aerogenes index in a chlorinated pool may be acceptable and yet streptococci be present. (This is at variance with a small amount of unpublished experimental work done on a chlorinated public supply where no streptococci were isolated from 50 ml. portions of water after passing the point of final chlorination.)

Mallman's (10) procedure for the determination of streptococci is as follows:

The lactose and dextrose nutrient broth tubes used in the coli-aerogenes group examinations are, after 48 hours initial incubation, held at room temperature for 72 hours, the liquid above the sediment withdrawn and the sediment examined microscopically using gentian violet stain. The cultures may be centrifugalized at the end of incubation instead of being allowed to settle. This would speed up the work but is thought by Mallman to be more trouble.

Houston's principal conclusion is confirmed by Clemsha and Mallman, namely that the presence of streptococci in water indicates recent and dangerous pollution. They show that the concentration is

lower than that of the coli-aerogenes group so that larger quantities of the sample must be examined than the highest dilution showing gas formation. This makes the test rather cumbersome and increases the number of laboratory manipulations. Houston insists that many positives will be lost by the microscopical examination of the original enrichment, which is recommended by Mallman. The latter's method is much less laborious.

RECENT WORK

Recently three articles have been published (11) dealing specifically with *S. salivarius*, *S. fecalis* and *S. equinus*. Their characteristics were studied in detail. The three are distinguished by the following:

	S. SALIVARIUS	S. FECALIS	S. EQUINUS
Morphology	Short chains	Pairs, few chains	Short chains
Temperature of growth, °C.:			
Lower tolerance	10°−	10°−	21° slow
Upper tolerance	45°	45°	45°
No growth	47°	50°±	48°
Litmus milk	Reduced after curdling	Reduced before curdling	No change
Ammonia in 4% peptone	−	+	−

Fermentation of various substances is erratic and not helpful in identification.

From the standpoint of drinking water production and swimming pool sanitation there may be no reason to distinguish between *S. salivarius* and *S. fecalis*. It seems probable, in the absence of information to the contrary, that *S. equinus* will be eliminated by purification processes as readily as the other two. Perhaps the simple determination of their presence or absence on the basis of morphology may be sufficient for water examination purposes.

SUMMARY

The significance of the test for streptococci in water has been given little attention in America. Dr. Houston of London investigated and used it over a period of thirty-five years and since his death his successor finds it of proven value.

It seems probable that it might be used to advantage on samples

from a distribution system at points where cross-connection pollution is suspected or from wells and springs, although the usual B. coli test may be almost as conclusive. There remains much work to do in respect to method of procedure as well as evaluation of results.

BIBLIOGRAPHY

(1) Clemsha, W. W. *The Bacteriology of Surface Waters of the Tropics.* (1912).

(2) Houston, A. C. *Rivers as Sources of Water Supply.* (1917).

(3) Houston, A. C. Metropolitan Water Board, Fifth and Tenth Research Reports.

(4) Houston, A. C. 25th Annual Report, London Metropolitan Water Board.

(5) Houston, A. C. 26th Annual Report, London Metropolitan Water Board.

(6) Houston, A. C. 27th Annual Report, London Metropolitan Water Board.

(7) Harold, C. H. H. 30th Annual Report, London Metropolitan Water Board.

(8) Mallman, W. L. and Sypien, A. Jour. A. P. H. A., 24, 681 (1934).

(9) Mallman, W. L. and Cary, W. Jour. A. P. H. A., 23, 35 (1933).

(10) Mallman, W. L. Jour. A. P. H. A., 18, 771 (1928).

(11) Sherman, J. M. and Associates. Jour. Bact., 33, 263 (1937).

ACTIVATED CARBON—ITS VALUE AND PROPER POINTS OF APPLICATION*

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"The availability of a cheap powdered activated carbon opens wide the field for experimentation with its use in combating tastes and odors in water supplies from existing water purification plants." This quotation is taken from a paper read by Malcolm Pirnie, Consulting Engineer, during the A.W.W.A. convention at Pittsburgh in 1931.

The use of powdered activated carbon had only begun and Mr. Pirnie's paper covered experiences in 15 plants. It was then estimated that approximately 35 plants throughout the country had already applied powdered activated carbon. Since that time the use of activated carbon in powdered form has extended to over 1,000 plants and has been used to the extent of many million pounds. Today powdered activated carbon is shipped from the United States throughout the World for use in water treatment. It is now apparent that Malcolm Pirnie had keen vision concerning what might be expected in the way of taste and odor removal through the use of powdered activated carbon.

The literature has since been filled with many references to this product for taste and odor removal; and to review the data would only be a repetition of what is already known. I have recently sent out about 150 questionnaires to plants applying activated carbon in powdered form and have received 137 replies. The purpose of this questionnaire was to obtain statistical information concerning the benefits of powdered activated carbon rather than attempt to express an individual opinion. The answers that were sought in the questionnaire included the following:

1—Types of tastes and odors that predominated.

2—Methods of feed.

* Presented before the Four States Section, April, 1937.

3—Methods of application.
4—Dosages used, etc.

All figures in the following tables will be "pegged" against the 137 questionnaires returned and percentages estimated from that figure.

Table 1 shows that the predominating taste and odor trouble was due to Algae. In number this totals 110 or equivalent to 80 percent. The next taste and odor that gave the greatest source of trouble was

TABLE 1 — *Sources of tastes and odors*; TABLE 2 — *Seasons of the year most troublesome*

Trade Waste	Algae	Leaves	Decaying Vegetation	Others	Location	Number of Plants Reporting	Spring	Summer	Fall	Winter
6	11		1		Canada	11	8	10	9	4
8	19	10	12	4	Pennsylvania	25	12	16	15	6
3	16	9	13	1	New York	21	10	13	9	5
7	7	4	9	5	Michigan	12	8	7	9	7
1	11	4	5	2	North Carolina	12	6	8	4	3
1	11	7	8	2	Illinois	11	10	9	8	4
	7	6	5	2	New Jersey	7	5	6	3	2
2	3	1	4	1	Indiana	6	2	5	2	3
	5	1	3		Texas	5		4	2	1
1	4	3	2		Maryland	4	2	3	3	2
	2	3	3	1	Missouri	3	2	2	2	1
1	2	2	2	1	Iowa	3	2	2	1	
1	3	1	1	2	Wisconsin	3	2	3	1	1
1	1	1	3	1	Kansas	3	3	2		1
1	1			2	West Virginia	2	1	1	1	1
	2		2		Florida	2	1	1		
1		1	2		Maine	2	1	1		1
	5	4	4		Others	5	2	2	4	3
34	110	57	79	24	Total	137	77	95	73	45

Decaying Vegetation. In number this totals 79 or equivalent to 58 percent. Taste and odor trouble due to leaves rated third place with 57 plants or 42 percent. Taste and odor trouble due to Trade Waste was reported by 34 plants or equivalent to 25 percent. Taste and odor trouble from other sources was reported by 24 plants or equivalent to 18 percent.

Table 2 indicates that the Summer season is the time of the year in which tastes and odors predominate as reported by 95 question-

naires equivalent to 69 percent. Fall and Spring seasons apparently are at a parity so far as taste and odor trouble is concerned as 73 and 77 questionnaires respectively so indicated. Winter is indicated as a troublesome season by 45 questionnaires or equivalent to 33 percent.

A study of the questionnaires shows that the summer season gives the greatest amount of trouble throughout the country in general

TABLE 3 — *Quantity of water treated*; **TABLE 4** — *Methods of feeding*

AMOUNT OF WATER REPORTED M.G.D.	NUMBER OF PLANTS USING CARBON CONTINUOUSLY	NUMBER OF MONTHS APPLIED AVERAGE	LOCATION	NUMBER OF PLANTS REPORTING	DRY FEED	SOLUTION FEED	MIXED WITH ROUTINE CHEMICAL
31.9	4	8.4	Canada	11	3	1	7
95.5	13	8.8	Pennsylvania	25	12	5	8
60.7	12	9.6	New York	21	13	1	6
303.8	7	10.7	Michigan	12	7	4	1
15.3	7	9.8	North Carolina	12	3	3	6
29.7	5	9.3	Illinois	11	5	3	5
44.3	5	10.0	New Jersey	7	3	2	1
62.9	4	10.2	Indiana	6	5	1	2
53.0	0	3.8	Texas	5	5		1
138.5	3	10.0	Maryland	4	2	1	1
9.2	1	6.3	Missouri	3	1	1	1
9.8	2	10.7	Iowa	3	3		
8.0	1	10.0	Wisconsin	3	3	1	
22.4	0	5.0	Kansas	3	3		1
10.0	0	6.5	West Virginia	2	1	1	
3.6	2	12.0	Florida	2		1	1
5.3	2	12.0	Maine	2	1	1	
16.9	3	11.0	Others	5	4	2	
920.8	71	9.3	Total or Average	137	74	28	41

and is not localized to any particular section. Some tastes and odors, particularly those due to trade wastes may be confined to a definite season of the year when a certain industry is in operation; for example, the beet sugar industry where operations are confined to a period of a few months.

Table 3 is very interesting in that it shows powdered activated carbon is being fed in many plants continuously. This is reported by 71 plants, equivalent to 52 percent. The remaining question-

naires reported feeding of powdered activated carbon during the year, from a few days to eleven months. Many plants reporting, indicated that carbon is being fed only when tastes and odors appear.

METHODS OF FEEDING

Table 4 indicates that a separate dry feed machine is the most common method of application. This is indicated by 74 questionnaires or equivalent to 54 percent. Mixing with routine chemicals is reported by 41 questionnaires or equivalent to 30 percent. Solution feed is reported by 28 questionnaires or equivalent to 20 percent. Other methods of feeding reported were crude to the extent of mixing the carbon in pails of water and applying this suspension directly to the filter, usually immediately after backwashing.

POINTS OF APPLICATION

Points of application indicated were:

After coagulation
During coagulation
Prior to coagulation

Split treatment; i.e. part to the mixing chamber and part after coagulation.

Table 5 shows that "prior to coagulation" is the point most commonly used, being reported by 49 questionnaires or equivalent to 36 percent. "During coagulation" is reported by 37 questionnaires, equivalent to 27 percent. Some doubt seems to exist on these questionnaires as to what is meant by prior to coagulation and what is meant by during coagulation. From a review of these questionnaires it is my personal opinion that these two can be combined, which would then account for a total of 86 questionnaires or equivalent to 63 percent. "After coagulation" is reported by 32 questionnaires or equivalent to 23 percent. "Split treatment" is reported by 17 questionnaires or equivalent to 12 percent. 33 questionnaires indicated the utilization of split treatment part of the time, but not as routine practice.

DOSAGE

Inasmuch as no attempt was made to confine the questionnaires to any particular part of the country, reports that came back showed dosages under a wide variety of conditions. A dose as low as 2 lbs. per million gallons and as high as 1788 lbs. per million gallons has

been indicated. The individual dose averaged for a particular plant showed as low as 2 lbs. per million gallons and as high as 429 lbs. per million gallons. This latter average figure is reported by Dundee, Michigan, where tastes and odors are reported as follows: (a) during the spring tastes and odors are due to Steffens waste from the beet sugar refineries; (b) during the summer to algae; (c) during the fall

TABLE 5 — *Points of application*; TABLE 6 — *Dosage of carbon reported*

Prior to coagulation	During coagulation	After coagulation	Split treatment: Regular	Split treatment: At times	Location	Number of plants	Reported average p.m.g.	Under normal conditions	Under extreme conditions	Average on basis of water treated p.m.g.	Average on basis of yearly pumpage p.m.g.
10		1			Canada	11	9.3	5–10	7–16	8.1	7.3
8	6	5	4	9	Pennsylvania	25	17.0	4–28	10–150	15.6	11.9
8	6	4	4	1	New York	21	10.7	2–15	4–300	16.0	9.7
2	4	6		5	Michigan	12	7.4	2–140	12–1788	29.0	6.0
3	5	4		4	North Carolina	12	10.5	3–16	10–42	10.9	6.8
4	3	2	2	3	Illinois	11	14.8	5–40	12–90	14.8	9.5
	5	2		2	New Jersey	7	12.7	5–20	12–40	15.5	13.1
2	1	2	1	3	Indiana	6	27.3	5–80	12–550	37.0	33.8
2	3				Texas	5	25.4	10–20	45–50	25.4	6.9
3	1			2	Maryland	4	34.0	2–70	10–215	23.3	9.8
1	1	1			Missouri	3	13.0	5–15	18–24	13.3	13.0
1	1		1	1	Iowa	3	18.0	8–30	50–200	20.5	16.3
1		1	1	1	Wisconsin	3	20.0	14–17	35–100	21.7	16.3
		1	2		Kansas	3	15.0	5–25	60–300	11.0	3.5
		1	1		West Virginia	2	25.0	35	230	37.8	26.1
1		1		1	Florida	2	26.0	12	48	13.9	13.9
		1			Maine	2	15.0	10–20	35	12.5	12.5
3	1		1	1	Others	5	90.6	2–400	4–1000	58.1	50.2
49	37	32	17	33	Total or Average	137	23.3	2–400	4–1788	23.3	11.2

to beet sugar process waste other than Steffens waste; and (d) during the winter to earthy tastes. With it all, however, the total cost of powdered carbon treatment at this plant would probably not exceed $1.50 per day.

Table 6 indicates that the over-all average dose reported in the 137 questionnaires is approximately 23 lbs. per million gallons. This figure is slightly higher than the over-all dose reported in a summary by the publication "Public Works" in their March, April

and May 1936 issues. If we were to segregate these 137 questionnaires and break them down into the classification of plants using powdered activated carbon continuously, we would find that the average dose figures even slightly less than that reported in the survey by "Public Works."

It has been our experience that during sudden taste and odor epidemics those plants that are not continuously feeding carbon or where a new plant is involved, the tendency is to use an over-dose, probably on the theory that if 20 lbs. per million gallons will do some good then surely 60 or 100 lbs. would do that much better. This therefore has the tendency when putting together statistical data to obtain information that will show slightly higher figures than would ordinarily be expected.

That powdered activated carbon has been a useful tool and accomplished the purpose for which it had been purchased is readily indicated when we find that out of these 137 questionnaires only three plants reported that they were unable satisfactorily to correct tastes and odors.

This information is substantiated in a paper by Oscar Gullans published in the "Journal of the American Water Works Association" January 1937 issue. In this paper Gullans shows that powdered activated carbon was the only successful treatment for the removal of tastes and odors from Lake Michigan water, which is conceded by all to be a very difficult water to treat. Many, who have had experiences with the use of powdered activated carbon, have indicated that in their opinion, tastes and odors are subject to removal by powdered activated carbon provided a sufficient dose is used. In some plants it is impossible through the lack of feeding equipment to apply the high dose required and whether this was true of the three plants in question is not known at this time.

BENEFITS

Incidental benefits that have been obtained through the application of powdered activated carbon is treated in Table 7.

(A) Of the 86 plants reporting its application prior to and during coagulation 63 questionnaires or 73 percent reported that better coagulation was secured. One questionnaire indicated that when 10 lbs. per million gallons or more were used prior to coagulation, much better coagulation was secured, but when the dosage was less than this amount better coagulation was not noticeable.

(B) Longer intervals between basin cleanings were reported by 23 questionnaires. Although not specifically mentioned in the questionnaire sludge stabilization has undoubtedly been accomplished in all plants feeding powdered activated carbon during and prior to the coagulation stage. Thus a taste and odor problem within the plant has been successfully combated.

TABLE 7 — *Incidental benefits* | TABLE 8 — *Chlorination and ammoniation*

BETTER COAGULATION	LONGER FILTER RUNS	LONGER INTERVALS OF BASIN CLEANINGS	LESS COAGULANT USED	LOCATION	NUMBER OF PLANTS	PRE CHLORINATION	PRE AMMONIATION	POST CHLORINATION	POST AMMONIATION
4			1	Canada	11	7	3	7	
13	2	2	2	Pennsylvania	25	19	11	22	3
13	4	5	3	New York	21	18	10	10	
2			1	Michigan	12	10	7	9	
7	2	3	3	North Carolina	12	6	4	7	1
3			1	Illinois	11	8	4	7	
3	1	2		New Jersey	7	6	4	6	
3	1	1	1	Indiana	6	4	3	5	1
2		2		Texas	5	2	2	5	1
3	1	2		Maryland	4	2		4	1
2	1	1	1	Missouri	3	2	1	3	
1		1		Iowa	3	1	2	3	1
1				Wisconsin	3	3	3	3	
				Kansas	3	3	3	2	1
1		1		West Virginia	2	1	1	1	
2	1	2		Florida	2	1		1	
				Maine	2	2		1	
3		1	1	Others	5	4	1	3	1
63	13	23	14	Total	137	99	59	99	10

(C) 13 plants reported securing longer filter runs, whereas 9 reported a shortening of filter runs. Of these 9 reporting shorter runs, 2 were feeding carbon prior to coagulation, 4 during coagulation, 1 after coagulation, and 2 split treatment. No mention was made in the questionaire as to the detention period between the coagulation basins and the filters, so we do not know if a short settling time may have been a contributing cause.

Mud ball formation in filters has been prevented at Highland Park, Mich., as reported by Irving Dahljelm. Apparently in this case the powdered activated carbon was adsorbing the organic compounds that previously caused mud ball formation.

(D) 14 questionnaires indicated less coagulant was used when powdered activated carbon was applied. This, of course, would naturally be in plants where carbon was applied during or prior to the coagulation period. Moberly, Mo., Poughkeepsie, N. Y., Ossining, N. Y., and Concord, N. C., reported savings in the alum dose of approximately 20 percent.

In table 8 is shown the number of plants utilizing pre-chlorination, pre-ammoniation, post-chlorination and post-ammoniation. It will be noted that 99 plants reported utilizing pre-chlorination and 99 plants using post-chlorination. As 137 plants reported, it will be realized that a fairly high proportion are utilizing both treatments. The proportion of plants utilizing pre-ammoniation is fairly high; being 43 percent. With regard to the plants reporting post-ammoniation, the figures should not be considered as at all conclusive. The reason for this is that no mention was made in the questionnaire regarding post-ammoniation and, therefore, those so reporting did so only to furnish additional information. Undoubtedly there are a large number of plants utilizing post-ammoniation.

DIFFICULTIES WITH ALGAE

Of the tastes and odors due to algae, the following types of algae have been specificially mentioned as giving trouble and later corrected with powdered activated carbon; i.e., Anabaena; Asterionella; Synedra; Synura.

Troublesome trade wastes have been reported as oil or gasoline waste; sugar plant waste, particularly Steffens Waste from beet sugar plants; and brine and organic contamination from chemical plants.

J. E. Goodell, Lancaster, Pa., reports that snow and ice lying upon the ground will absorb ground odors. A sudden thaw will carry those odors into the streams and strongly affect the taste. It is believed that a bad flavor of the water is usually caused by the action of the chlorine upon the trace of organic matter in the water at the times when the Conestoga is muddy. He has been going upon the supposition that if activated carbon is added to the coagulated water, odors will be adsorbed, and filtration will remove the

objectionable material. Then the proper doses of ammonia and chlorine will have no bad effect.

E. C. Goehring, Beaver Falls, Pa., reports that the operating conditions to combat tastes and odors vary with the seasons. During the summer tastes and odors are due mostly to algae, which originate in the Shenango River. The Pymatuning Swamp, which is at the head waters of this river, discharges water which is of a quality in which algae flourish very prolifically. A random microscopic examination of a sample of this stream at Sharon, Pa., taken last summer indicated that there were approximately five thousand algae organisms per cc. in the raw water, with twenty-seven different types identified. Most of these were of the chlorophyceae and cyanophyceae types. Inasmuch as the Shenango River is a tributary of the Beaver, the plant gets the benefit of this algae-bearing water after it has passed through the industrial cities of New Castle and Farrell, where most of these organisms, due to acid wastes, are disintegrated. With algae tastes and odors, it has been found that activated carbon is quite effective in eliminating most of the tastes.

At Newport News, Virginia, tastes and odors are reported to be due to algae, leaves and decaying vegetation. J. M. Pharr, Chemist, reports that during the period of extreme taste and odor trouble, which usually falls in February and September, the carbon dosage will run as high as 75 pounds per million gallons. It is preferable to add the carbon to the raw water but during these periods it sometimes becomes necessary to use a split feed treatment, in which case a dose of 12 pounds per million gallons is fed directly on top of the filter beds. The carbon is fed to the filters with a barrel arrangement of their own design. An additional dose of as much as 60 pounds per million gallons is added to the raw water ahead of the alum with a dry feeder machine. It is to be understood that the figures are the maximum doses fed, this period of maximum feed seldom lasting over several days. With this set up it is possible to overcome extreme taste and odor trouble in the Newport News' impounded water supply.

A. D. Stalker, City Engineer, of Ottawa, Canada, reports that in his opinion algae taste in the Ottawa water supply is derived from the putrefaction of more or less formless debris in the hydrated alumina sludge deposited in the settling basins, rather than from living organisms. There is a large amount of spirogyra and other filamentous forms on the rocks and stones along the banks of the

Ottawa River which have an offensive odor when left dry by low water conditions. This is believed to be the chief reason for tastes in the water supply.

A very interesting method of treatment is reported by Carl Haynes of Moberly, Mo., and is quoted as follows:

"The first step in this odor control is the use of copper sulphate. We dump this into an old alum bag and hold it out of the side of a motor boat, then we circle and scatter this over about ten acres just in front of the intake of the dam and flow line. We repeat this operation in a week or ten days, or just as long as there is any odor in the water. The next step is to put HTH in the intake just ahead of the pump which sends the water to town. We have a 16 inch flow line four miles long. The chlorine kills all of the algae and most of the other organisms in this flow line, then we come to the dosing pump. We give this a shot of chlorine, then we go to the settling basin and we give that a shot of chlorine also. Now this is where the activated carbon comes in. We have practically killed all of the bacteria which produces these odors, or at least have stopped their growth. We apply the activated carbon in the dosing chamber simultaneously with the lime and alum, and find that it helps to create a better floc and also seeds down the sludge in the settling basins. As a result of all of these operations, we feel that we have as good a water as can be found anywhere; it is clear, sparkling and has a very pleasant taste."

W. Strockbine reports that at Reading, Pa., probably the worst offender so far as taste goes has been anabaena, before facilities for applying activated carbon were available, and synura since. There have even been tastes due to synedra in a distributing reservoir when they were present in large numbers. Mr. Strockbine reports that difficulties encountered with decaying vegetation are due to a new surface which has recently been covered by water, thus submerging dead growths from shallow areas, leaves, etc.

P. L. McLaughlin reports that at Charleston, W. Va., a dose of 35 lbs./M.G. might be considered the average necessary to eliminate ordinary tastes and odors contributed by algae and mild sewage pollution, and under such conditions activated carbon is applied between the two settling basins.

During the winter months when the river is near freezing temperature, oil or gasoline waste give much trouble at Charleston and carbon

is then often applied to the raw and settled water, as well as at the main point of application between the two basins. The total dose of carbon necessary to produce a satisfactory finished water under these conditions sometimes runs as high as 230 lbs./M.G. It is reported that powdered activated carbon has been successful in removing all the types of tastes and odors experienced at Charleston within the past few years.

J. C. Richardson reports that at Saginaw, Michigan, there is no one type of algae encountered. Trade wastes, however, are mainly of three types; sugar plant wastes from four plants slicing some 5000 tons daily; brine and oil contamination from oil fields and six or eight refineries; brine and organic contamination from a chemical plant, the latter waste containing chloro-phenols and other oxidized phenols.

SUMMARY

Sterilization of water to prevent water borne diseases is well recognized throughout the country and state regulations have been adopted almost universally, necessitating the application of chlorine or chlorinous compounds. From the number of plants reporting the continuous use of powdered activated carbon, as well as a number of plants using it when tastes and odors occur, and considering the wide discussion over a period of years of the application of ammonia, it is apparent that there is a constant trend towards the furnishing of a palatable drinking water. It is reasonable to expect that within the next few years standards of palatability may be adopted following the same procedure as did sterilization of public water supplies.

We all appreciate that the average layman, given his choice between an unpalatable safe water and a palatable water of doubtful safety, will usually choose the latter. This accounts, to a large extent, for the continued use of private wells, spring waters, and the like, which to the average layman represent all that is desirable in drinking water but, because sterilization has not been used, epidemics are continually reported. Therefore, the sooner that all public water supplies are treated with activated carbon or other substances for taste and odor control, the less reason will exist for the continued use of private supplies. When a consumer can be furnished from a public water supply a palatable water, a sparkling water, and a safe water then the necessity or desire for using private supplies will cease.

SUPREME COURT OF THE UNITED STATES[1]

WILLIAM WHITLOCK BRUSH, PETITIONER, vs. COMMISSIONER OF INTERNAL REVENUE	On Writ of Certiorari to the United States Circuit Court of Appeals for the Second Circuit.

Mr. Justice SUTHERLAND delivered the opinion of the Court.

The question brought here for determination is whether the salary of petitioner as Chief Engineer of the Bureau of Water Supply of the City of New York is a part of his taxable income for the purposes

[1] *Editor's Note:* From the time that the Federal income tax law became operative, the question of exemptions for municipal water department employees has been raised. The claim by the firm of Metcalf and Eddy for exemption from taxation of that portion of their income derived from their practice relating to municipal water supply was denied in 1926. The claim of Charles F. Denman, General Manager of the Des Moines Water Works, was denied by the Court of Appeals in 1934.

In the meantime, William W. Brush, as Chief Engineer of New York City's department of Water Supply, Gas and Electricity, had made a claim for exemption from federal income taxation of that portion of his income derived from that employment. The claim was denied by the Board of Tax Appeals. This denial was affirmed by the United States Circuit Court of Appeals. A review by the Supreme Court was requested and granted (No. 451—October term, 1936); briefs submitted; and, on March 15th, 1937, a decision handed down in favor of Mr. Brush. Both the majority and minority opinions are published herewith in full because of their natural interest to the entire water supply field.

It is a regrettable fact that the interest to the field is so little conditioned upon the possible reduction of water department employees' income tax. The great majority of the water departments in the United States pay their employees upon such a basis that, after deductions for dependents are made, little taxable income remains.

But a considerable array of legal precedent had been established to the effect that water department activities were a proprietary rather than a governmental function of a municipality. How many of these precedents are now overturned is left to legal minds to discern.

Press comment has been voluminous. It has been suggested by some that the decision opens up the path to acceptance of many other municipally controlled enterprises as functions of government; by others, that the states (and their political subdivisions) cannot properly withdraw from the federal taxing power a wide list of enterprises simply by claiming they are of public benefit.

of the federal income-tax law. The answer depends upon whether the water system of the city was created and is conducted in the exercise of the city's governmental functions. If so, its operations are immune from federal taxation and, as a necessary corollary, "fixed salaries and compensation paid to its officers and employees in their capacity as such are likewise immune." *New York ex rel. Rogers* v. *Graves*, *299* U. S. (January 4, 1937).

Petitioner holds his office as Chief Engineer by statutory authority, with a fixed annual salary of $14,000. He exercises supervision over the engineering details connected with the supplying of water for public purposes and for consumption by the inhabitants of the city; supervises the protection of the water supply from pollution; and generally exercises control over the operation of the water system, its personnel, expenditure of money and other matters relating thereto.

In the early history of the city, water was furnished by private companies; but a century or more ago, the city itself began to take over the development and distribution. In 1831, the Board of Aldermen declared its dissatisfaction with the private control, and resolved that the powers then vested in private hands should be repealed by the legislature and vested exclusively in the corporation of the City of New York. This, in effect, was initiated in 1833 (L. 1833, ch. 36); and, soon thereafter, the city constructed municipal water works, and, with slight exceptions, private control and operation ceased. The sources of water supply furnished by such companies as remain is approaching exhaustion, and the water furnished is of a quality inferior to that supplied by the municipality. From 1833 to the present time, additions to the water supply and system have been steadily made until the cost has mounted to more than $500,000,000; and it is estimated that additional expenditures of a quarter of a billion dollars will be necessary. The cost of bringing water from the Catskills alone amounted to approximately $200,000,000. The municipal outstanding bonded indebtedness incurred for supplying the city with water amounts to an enormous sum. More than half the entire population of the state is found within the municipal boundaries. The action of the city from the beginning has been taken under legislative authority.

The Commissioner of Internal Revenue having assessed a deficiency tax against petitioner in respect of his salary, petitioner sought a redetermination at the hands of the Board of Tax Appeals. That

board sustained the commissioner and decreed a deficiency against petitioner of $256.27 for the year 1931. Upon review, the court below affirmed the decree of the board. 85 F. (2d) 32. While the sum involved is small, we granted the writ of certiorari because of the obvious importance of the question involved.

The phrase "governmental functions," as it here is used, has been qualified by this court in a variety of ways. Thus, in *South Carolina v. United States*, 199 U. S. 437, 461, it was suggested that the exemption of state agencies and instrumentalities from federal taxation was limited to those which were of a *strictly* governmental character, and did not extend to those used by the state in carrying on an ordinary private business. In *Flint* v. *Stone Tracy Co.*, 220 U. S. 107, 172, the immunity from taxation was related to the *essential* governmental functions of the state. In *Helvering* v. *Powers*, 293 U. S. 214, 225, we said that the state "cannot withdraw sources of revenue from the federal taxing power by engaging in businesses which constitute a departure from *usual* governmental functions and to which, by reason of their nature, the federal taxing power would normally extend." And immunity is not established because the state has the power to engage in the business for what the state conceives to be the public benefit. *Idem.* In *United States* v. *California*, 297 U. S. 175, 185, the suggested limit of the federal taxing power was in respect of activities in which the states have *traditionally* engaged.

In the present case, upon the one side, stress is put upon the adjective "essential," as used in the *Flint* v. *Stone Tracy* case, while, on the other side, it is contended that this qualifying adjective must be put aside in favor of what is thought to be the greater reach of the word "usual," as employed in the *Powers* case. But these differences in phraseology, and the others just referred to, must not be too literally contradistinguished. In neither of the cases cited, was the adjective used as an exclusive or rigid delimitation. For present purposes, however, we shall inquire whether the activity here in question constitutes an essential governmental function within the proper meaning of that term; and in that view decide the case.

There probably is no topic of the law in respect of which the decisions of the state courts are in greater conflict and confusion than that which deals with the differentiation between the governmental and corporate powers of municipal corporations. This condition of conflict and confusion is confined in the main to decisions relating to liability in tort for the negligence of officers and agents of the

municipality. In that field, no definite rule can be extracted from the decisions.[2] It is true that in most of the state courts, including those in the State of New York, it is held that the operation of water works falls within the category of corporate activities; and the city's liability is affirmed in tort actions arising from negligence in such operation. But the rule in respect of such cases, as we pointed out in *Trenton* v. *New Jersey*, 262 U. S. 182, 192, has been "applied to escape difficulties, in order that injustice may not result from the recognition of technical defenses based upon the governmental character of such corporations"; and the rule is hopelessly indefinite, probably for that very reason.

This is not, however, an action for personal injuries sounding in tort, but a proceeding which seeks in effect to determine whether immunity from federal taxation, in respect of the activity in question, attaches in favor of a *state-created municipality*—an objective so different in character from that sought in a tort action as to suggest caution in applying as the guide to a decision of the former a local rule of law judicially adopted in order to avoid supposed injustices which would otherwise result in the latter. We have held, for example, that the sale of motorcycles to a municipal corporation for use in its police service is not subject to federal taxation, because the maintenance of such a service is a governmental function. *Indian Motocycle Co.* v. *United States*, 283 U. S. 570, 579. And while it is true that the weight of authority in tort actions accords with that view, there are state decisions which affirm the liability of a municipality for personal injury resulting from the negligence of its police officials under the circumstances presented in the respective cases dealt with.[3] Nevertheless, our decision in the *Indian*

[2] This is brought out in a careful and detailed review by Professor Borchard in that portion of his general discussion of "Government Liability in Tort" dealing with municipal corporations, to be found in (1924–5) 34 Yale L. J. 129–143, 229–258, in the course of which he says (p. 129): "Disagreement among the courts as to many customary municipal acts and functions may almost be said to be more common than agreement and the elaboration of the varying justifications for their classification is even less satisfying to any demand for principle in the law. Indeed, so hopeless did the effort of the courts to make an appropriate classification of functions appear to the Supreme Court of South Carolina that they determined to abandon the distinction between governmental and corporate acts."

[3] See Herron v. Pittsburg, 204 Pa. St. 509, 513; Jones v. City of Sioux City, 185 Iowa 1178, 1185; Twist v. City of Rochester, 55 N. Y. Supp. 850. Compare, Kunz v. City of Troy, 104 N. Y. 344, 348, with Altvater v. Mayor &c. of Balto. 31 Md. 462.

Motocycle case did not rest in the slightest degree upon a consideration of the state rule in respect of tort actions, but upon a broad consideration of the implied constitutional immunity arising from the dual character of our national and state governments.

The rule in respect of municipal liability in tort is a local matter; and whether it shall be strict or liberal or denied altogether is for the state which created the municipality alone to decide (*Detroit* v. *Osborne*, 135 U. S. 492, 497—498)—provided, of course, the federal Constitution be not infringed. But a federal tax in respect of the activities of a state or a state agency is an imposition by one government upon the activities of another, and must accord with the implied federal requirement that state and local governmental functions be not burdened thereby. So long as our present dual form of government endures, the states, it must never be forgotten, "are as independent of the general government as that government within its sphere is independent of the States." *The Collector* v. *Day*, 11 Wall. 113, 124. And, as it was said in *Texas* v. *White*, 7 Wall. 700, 725, and often has been repeated—"the preservation of the States, and the maintenance of their governments, are as much within the design and care of the Constitution as the preservation of the Union and the maintenance of the National government." The unimpaired existence of both governments is equally essential. It is to that high end that this court has recognized the rule, which rests upon necessary implication, that neither may tax the governmental means and instrumentalities of the other. *The Collector* v. *Day*, *supra*, p. 127. In the light of these considerations, it follows that the question here presented is not controlled by local law but is a question of national scope to be resolved in harmony with implied constitutional principles of general application. Compare *Workman* v. *New York City, Mayor, &c.*, 179 U. S. 552, 557. This indicated dissimilarity constitutes a distinction which is fundamental; and we put aside the state decisions in tort actions as inapposite. Compare *Atlantic Cleaners & Dyers* v. *United States*, 286 U. S. 427, 433 *et seq.*

We thus come to a situation, which the courts have frequently been called upon to meet, where the issue cannot be decided in accordance with an established formula, but where points along the line "are fixed by decisions that this or that concrete case falls on the nearer or farther side." *Hudson Water Co.* v. *McCarter*, 209 U. S. 349, 355. We are, of course, quite able to say that certain functions exercised by a city are clearly governmental—that is, lie upon the nearer side of the line—while others are just as clearly

private or corporate in character, and lie upon the farther side. But between these two opposite classes, there is a zone of debatable ground within which the cases must be put upon one side or the other of the line by what this court has called the gradual process of historical and judicial "inclusion and exclusion." *Continental Bank* v. *Rock Island Ry.*, 294 U. S. 648, 670, and cases cited.

We think, therefore, that it will be wise to confine, as strictly as possible, the present inquiry to the necessities of the immediate issue here involved, and not, by an attempt to formulate any general test, risk embarrassing the decision of cases in respect of municipal activities of a different kind which may arise in the future. Cf. *Euclid* v. *Ambler Co.*, 272 U. S. 365, 397; *Metcalf & Eddy* v. *Mitchell*, 269 U. S. 514; 523. In the case last named we had occasion to point out the difficulty, albeit the necessity, as cases arise within the doubtful zone, of drawing the line which separates those activities which have some relation to government but are subject to taxation from those which are immune. "Experience has shown," we said, "that there is no formula by which that line may be plotted with precision in advance. But recourse may be had to the reason upon which the rule rests, and which must be the guiding principle to control its operation. Its origin was due to the essential requirement of our constitutional system that the federal government must exercise its authority within the territorial limits of the states, and it rests on the conviction that each government, in order that in may administer its affairs within its own sphere, must be left free from undue interference by the other."

The public interest in the conservation and distribution of water for a great variety of purposes—ranging from ordinary agricultural, domestic and sanitary uses, to the preservation of health and of life itself—is obvious and well settled. For the modern city, such conservation and distribution of water in sufficient quantity and in a state of purity is as vital as air. And this vital necessity becomes more and more apparent and pressing as cities increase in population and density of population. It has found, so far, its culminating point in the vast and supreme needs of the City of New York.

One of the most striking illustrations of the public interest in the use of water and the governmental power to deal with it is shown in legislation and judicial pronouncement with respect to the arid-land states of the far west. In some of them, the state constitution asserts public ownership of all unappropriated non-navigable waters.

In Utah, while it was still a territory, a statute conferred the right upon individual land owners to condemn rights-of-way across the lands of others in order to convey water to the former for irrigation purposes, and declared that such condemnation was for a "public use." This court upheld the statute. *Clark* v. *Nash,* 198 U. S. 361. We said that what is a public use may depend upon the facts surrounding the subject; pointed out the vital need of water for irrigation in the arid-land states, a need which did not exist in the states of the east and where, consequently, a different rule obtained; and held that the court must recognize the difference of climate and soil which rendered necessary differing laws in the two groups of states.

Many years ago, Congress, recognizing this difference, passed the Desert Land Act (c. 107, 19 Stat. 377), by which, among other things, the waters upon the public domain in the arid-land states and territories were dedicated to the use of the public for irrigation and other purposes. Following this act, if not before, all non-navigable waters then on and belonging to that part of the national domain became *publici juris,* subject to the plenary control of the arid-land states and territories with the right to determine to what extent the rule of appropriation or the common-law rule in respect of riparian rights should obtain. *Power Co.* v. *Cement Co.,* 295 U. S. 142, 155 *et seq.* And in *Kansas* v. *Colorado,* 206 U. S. 46, 94, this court entertained and decided a controversy between two states involving the right of private appropriators in Colorado to divert waters for the irrigation of lands in that state from a river naturally and customarily flowing into the State of Kansas. It was held (p. 99) that such a controversy rises "above a mere question of local private right and involves a matter of state interest, and must be considered from that standpoint." Cf. *Hudson Water Co.* v. *McCarter,* 209 U. S. 349, 355; *New Orleans Gas Co.* v. *Drainage Comm.,* 197 U. S. 453, 460; *Houck* v. *Little River District,* 239 U. S. 254, 261.

In *New Orleans* v. *Morris,* 105 U. S. 600, 602, the city had conveyed its water works to a corporation formed for the purpose of maintaining and enlarging them. The city received as consideration shares of stock, which a state statute declared should not be liable to seizure for the debts of the city. It was held the statute did not impair the obligation of any contract, since the shares represented the city's ownership in the water works which had, before the enactment of the statute, been exempted from seizure and sale.

This ruling was put upon the ground that the water works were of such public utility and necessity that they were held in trust for the use of the citizens the same as public parks and public buildings.

While these cases do not decide, they plainly suggest, that municipal water works created and operated in order to supply the needs of a city and its inhabitants are public works and their operation essentially governmental in character. Other decisions of this court, however, more directly support that conclusion.

We recently have held that the bankruptcy statutes could not be extended to municipalities or other political subdivisions of a state. *Ashton* v. *Cameron County Dist.*, 298 U. S. 513. The respondent there was a water-improvement district organized by law to furnish water for irrigation and domestic uses. We said (pp. 527-528) that respondent was a political subdivision of the state "created for the local exercise of her sovereign powers. . . . Its fiscal affairs are those of the State, not subject to control or interference by the National Government, unless the right so to do is definitely accorded by the Federal Constitution." In support of that holding, former decisions of this court with respect to the immunity of states and municipalities from federal taxation were relied upon as apposite. The question whether the district exercised governmental or merely corporate functions was distinctly in issue. The petition in bankruptcy alleged that the district was created with power to perform "the proprietary and/or corporate function of furnishing water for irrigation and domestic uses. . . ." The district judge held that the district was created for the local exercise of state sovereign powers; that it was exercising "a governmental function"; that its property was public property; that it was not carrying on private business, but public business. That court, having denied the petition for want of jurisdiction, the district submitted a motion for a new trial in which it assigned, among other things, that the court erred in holding that petitioner was created for the purpose of performing governmental functions, "for the reason that the Courts of Texas, as well as the other Courts in the Nation, have uniformly held that the furnishing of water for irrigation was purely a proprietary function. . . "Substantially the same thing was repeated in other assignments of error. In the petition for rehearing in this court, the district challenged our determination that respondent was a political subdivision of the state "created for the local exercise of her soverign powers," and asserted to the contrary that the facts

would demonstrate that "respondent is a corporation organized for essentially proprietary purposes." It is not open to dispute that the statements quoted from our opinion in the *Ashton* case were made after due consideration, and the case itself decided and the rehearing denied in the light of the issue thus definitely presented. Compare *Bingham* v. *United States*, 296 U. S. 211, 218–219.

"No higher police duty rests upon municipal authority," this court said in *Columbus* v. *Mercantile Trust Co.*, 218 U. S. 645, 658, "than that of furnishing an ample supply of pure and wholesome water for public and domestic uses. The preservation of the health of the community is best obtained by the discharge of this duty, to say nothing of the preservation of property from fire, so constant an attendant upon crowded conditions of municipal life."

In *Dunbar* v. *City of New York*, 251 U. S. 516, we sustained a charter provision giving a lien for water charges upon a building in which the water had been used, although the charges had been incurred by tenants and not by the owner, saying—"And as a supply of water is necessary it is only an ordinary and legal exertion of government to provide means for its compulsory compensation."

In *German Alliance Ins. Co.* v. *Home Water Co.*, 226 U. S. 220, the City of Spartansburg had entered into a contract with the respondent by which the latter was empowered to supply the city and its inhabitants with water suitable for fire, sanitary and domestic purposes. The petitioner had issued a policy of fire insurance upon certain property, which was destroyed by fire. It paid the amount of the loss, and took an assignment from the insured of all claims and demands against any person arising from or connected with the loss. It brought suit against the respondent on the ground that the fire could easily have been distinguished if respondent had complied with its contract. This court held that the reaction was not maintainable for reasons which appear in the opinion. The City, it was said, was under no *legal* obligation to furnish water, and it did not subject itself to a new or greater liability because it voluntarily undertook to do so (pp. 227–228). "It acted in a governmental capacity, and was no more responsible for failure in that respect that it would have been for failure to furnish adequate police protection."

We conclude that the acquisition and distribution of a supply of water for the needs of the modern city involve the exercise of essential governmental functions, and this conclusion is fortified by a con-

sideration of the public uses to which water is put. Without such a supply, public schools, public sewers so necessary to preserve health, fire departments, street sprinkling and cleaning, public buildings, parks, playgrounds, and public baths, could not exist. And this is equivalent, in a very real sense, to saying that the city itself would then disappear. More than one-fourth of the water furnished by the city of New York, we are told by the record, is utilized for these public purposes. Certainly, the maintenance of public schools, a fire department, a system of sewers, parks and public buildings, to say nothing of other public facilities and uses, calls for the exercise of governmental functions. And so far as these are concerned, the water supply is a necessary auxiliary, and, therefore, partakes of their nature. *New York ex rel. Rogers* v. *Graves*, (January 4, 1937). Moreover, the health and comfort of the city's population of 7,000,000 souls, and in some degree their very existence, are dependent on an adequate supply of pure and wholesome water. It may be, as it is suggested, that private corporations would be able and willing to undertake to provide a supply of water for all purposes; but if the State and City of New York be of opinion, as they evidently are, that the service should not be entrusted to private hands but should be rendered by the city itself as an appropriate means of discharging its duty to protect the health, safety and lives of its inhabitants, we do not doubt that it may do so in the exercise of its essential governmental functions.

We find nothing that detracts from this view in the fact that in former times the business of furnishing water to urban communities, including New York, in fact was left largely, or even entirely, to private enterprise. The tendency for many years has been in the opposite direction, until now in nearly all the larger cities of the country the duty has been assumed by the municipal authorities. Governmental functions are not to be regarded as non-existent because they are held in abeyance, or because they lie dormant, for a time. If they be by their nature governmental, they are none the less so because the use of them has had a recent beginning.

The principle finds illustration in our decision in *Shoemaker* v. *United States*, 147 U. S. 282, 297, where it was held that land taken by an exercise of the power of eminent domain for the establishment of Rock Creek Park in the District of Columbia was taken for a public use, and that the amount required to be paid was validly assessed upon lands in the district specially benefited thereby. At the begin-

ning of the opinion in that case, this court said: "In the memory of men now living, a proposition to take private property, without the consent of its owner, for a public park, and to assess a proportionate part of the cost upon real estate benefited thereby, would have been regarded as a novel exercise of legislative power." It was pointed out that Central Park in New York was the first place provided for the inhabitants of any city or town in the United States as a pleasure ground for rest and exercise in the open air, but that in 1892, when the opinion was written, there was scarcely a city of any considerable size in the country that did not have, or had not projected, such parks.

Respondent contends that the municipality, in supplying water to its inhabitants, is engaged in selling water for profit; and seems to think that this, if true, stamps the operation as private and not governmental in character. We first pause to observe that the overhead due to the enormous cost of the system, and the fact that so large a proportion of the water is diverted for public use, rather plainly suggests that no real profit is likely to result. And to say that, because the city makes a charge for furnishing water to private consumers, it follows that the operation of the water works is corporate and not governmental, is to beg the question. What the city is engaged in doing in that respect is rather rendering a service than selling a commodity. If that service be governmental it does not become private because a charge is made for it, or a profit realized. A state, for example, constructs and operates a highway. It may, if it choose, exact compensation for its use from those who travel over it (see *Bingham* v. *Golden Eagle Lines*, 297 U. S. 626, 628); but this does not destroy the claim that the maintenance of the highway is a public and governmental function. The state or the city may exact a tuition charge for instruction in the public schools; but thereby the maintenance of the public schools does not cease to be a function of the government. The state exacts a fee for issuing a license or granting a permit; for recording a deed; for rendering a variety of services in the judicial department. Do these various services thereby lose their character as governmental functions? The federal Post-Office Department charges for its services; but no one would question the fact that its operation calls into exercise a governmental function.

The contention is made that our decisions in *South Carolina* v. *United States*, 199 U. S. 437, 461, 462, and *Flint* v. *Stone Tracy Co.*,

220 U. S. 107, 172, are to the effect that the supplying of water is not a governmental function; but in neither case was that question in issue, and what was said by the court was wholly unnecessary to the disposition of the cases and merely by way of illustration. Expressions of that kind may be respected, but do not control in a subsequent case when the precise point is presented by decision. *Osaka Shosen Kaisha Line* v. *United States*, 299 U. S. (February 1, 1937), and authorities cited. The precise point is presented here, has been fully considered, and is decided otherwise. Neither *Ohio* v. *Helvering*, 292 U. S. 360, nor *Helvering* v. *Powers*, 293 U. S. 214, relied upon by respondent, is in point. What has already been said distinguishes those cases from the one now under consideration. We have not failed to give careful consideration to *Blair* v. *Byers*, 35 F. (2d) 326, and *Denmam* V. *Comm'r Int. Rev.*, 73 F (2d) 193, both of which take a view contrary to that which we have expressed. To the extent of this conflict, those cases are disapproved. Both rely on *South Carolina* v. *United States* and *Flint* v. *Stone Tracy Co.*, *supra*, which we have already distinguished.

Reversed.

Mr. Justice Stone and Mr. Justice Cardozo, concurring in the result:

We concur in the result upon the ground that the petitioner has brought himself within the terms of the exemption prescribed by Treasury Regulation 74, Article 643, which for the purposes of this case may be accepted as valid, its validity not being challenged by counsel for the Government.

In the absence of such a challenge no opinion is expressed as to the need for revision of the doctrine of implied immunities declared in earlier decisions.

We leave that subject open.

Mr. Justice Roberts, dissenting. I regret that I am unable to concur in the opinion of the court. I think that the judgment should be affirmed.

There is no occasion now to discuss the dual character of our form of government, and the consequent dual allegiance of a citizen of a state to his state and to the United States, to elaborate the thesis that the integrity of each government is to be maintained against invasions by the other or to reiterate that the implied immunity of the one from taxation by the other springs from the necessity that neither shall, by the exercise of the power to tax, burden, hinder or

destroy the operation or existence of the other. There is universal recognition of the truth of these tenets, and of their fundamental relation to the preservation of the constitutional framework of the nation. Our difficulties arise, not in their statement as guiding principles, but, as in this instance, in their application to specific cases.

The frank admissions of counsel at the bar concerning the confusion and apparent inconsistency in administrative rulings as to the taxability of compensation of municipal employees seems to call for an equally candid statement that our decisions in the same field have not furnished the executive a consistent rule of action. The need of equitable and uniform administration of tax laws, national and state, and the just demand of the citizen that the rules governing the enforcement of those laws shall be ascertainable require an attempt at rationalization and restatement.

It seems to me that the reciprocal rights and immunities of the national and a state government may be safequarded by the observance of two limitations upon their respective powers of taxation. These are that the exactions of the one must not discriminate against the means and instrumentalities of the other and must not directly burden the operations of that other. To state these canons otherwise: an exaction by either government which hits the means or instrumentalities of the other infringes the principle of immunity if it discriminates against them and in favor of private citizens or if the burden of the tax be palpable and direct rather than hypothetic and remote. Tested by these criteria the imposition of the challenged tax in the instant case was lawful.

The petitioner is a citizen of New York. By virtue of that status he is also a citizen of the United States. He owes allegiance to each government. He derives income from the exercise of his profession. His obligation as a citizen is to contribute to the support of the governments under whose joint protection he lives and pursues his calling. His liability to fulfill that obligation to the national government by payment of income tax upon his salary would be unquestioned were it not for the character of his employer. If the water works of New York City were operated by a private corporation under a public franchise and if the petitioner held a like position with the corporation, there could be no question that the imposition of a federal income tax, measured by his compensation, would be justified. If petitioner, instead of holding a so-called official posi-

tion under the municipal government of New York City, were consulted from time to time with respect to its water problems his compensation would be subject to income tax. (*Metcalf* and *Eddy* v. *Mitchell*, 269 U. S. 514.) He is put into an untaxable class upon the theory that as an official of the municipality, which in turn is an arm of the state, he is an "instrumentality" of the state, and to tax him upon his salary is to lay a burden upon the state government which, however trifling is forbidden by the implied immunity of the state from burdens imposed by the United States. The petitioner seeks to show the reality of the supposed burden by the suggestion that if his salary and the compensation of others employed by the city is subject to federal income tax, the municipality will be compelled to pay higher salaries in order to obtain the services of such persons and the consequent aggregate increase in outlay will entail a heavy financial load. We know, however, that professional services are offered in the industrial and business field; and that while there is no hard and fast standard of compensation, and men bargain for their rewards, salaries do bear some relation to experience and ability. There is a market in which a professional man offers his services and municipalities are bidders in that market. We know further that those in private employment holding positions comparable to that of the petitioner pay a tax equal to that levied upon him. It is clear that any consideration of the petitioner's immunity from federal income tax would be altogether remote, impalpable and unascertainable in influencing him to accept a position under the municipality rather than under a private employer.

In reason and logic it is difficult to differentiate the present case from that of a private citizen who furnishes goods, performs work or renders service to a state or a municipality under a contract or an officer or employe of a corporation which does the same. Income tax on the compensation paid or the profit realized is a necessary cost incident to the performance of the contract and as such must be taken into account in fixing the consideration demanded of the city government. In quite as real a sense, as in this case, the taxation of income of such persons and, as well, the taxation of the corporation itself, lays a burden upon the funds of the state or its agency. Nevertheless, the courts have repeatedly declared that the doctrine of immunity will not serve to exempt such persons or corporations from the exaction.

The importance of the case arises out of the fact that the claimed

exemption may well extend to millions of persons (whose work nowise differs from that of their fellows in private enterprise) who are employed by municipal subdivisions and districts throughout the nation and that, on the other hand, the powers of the states to tax may be inhibited in the case of hundreds of thousands of similar employes of federal agencies of one sort or another. Such exemptions from taxation ought to be strictly limited. They are essentially unfair. They are unsound because federal or state business ought to bear its proportionate share of taxation in order that comparison may be made between the cost of conducting public and private business.

We are here concerned only with the question of the taxation of salaries or compensation received by those rendering to a municipality services of the same kind as are rendered to private employers and need not go beyond the precise issue here presented. We have no concern with the exaction of a sales tax by the federal government on sales to a state government or one of its subdivisions, or the reverse; we are not called upon to define the power to levy taxes upon real property owned by a state or by the national government. We have no occasion to discuss the power of either government to impose excise taxes upon transactions of the other or upon the evidence of such transactions. Nor are we called upon here to determine the validity of a nondiscriminatory tax upon the salary of a governmental officer whose duties and functions have no analogue in the conduct of a business or the pursuit of a profession, but are both peculiar to and essential to the operation of government. The sole question here is whether one performing work or rendering service of a type commonly done or rendered in ordinary commercial life for gain is exempt from the normal burden of a tax on that gain for the support of the national government because his compensation is paid by a state agency instead of a private employer. I think the imposition of a tax upon such gain where, as here, the tax falls equally upon all employed in like occupation, and where the supposed burden of the tax upon state government is indirect, remote, and imponderable, is not inconsistent with the principle of immunity inherent in the constitutional relation of state and nation.

Mr. Justice BRANDEIS joins in this opinion.

REPORT OF THE SECRETARY FOR YEAR ENDING DECEMBER 31, 1936

To the Members of the American Water Works Association:

The By-Laws require that the Secretary shall have an annual audit made of the books of the Association.

The records for 1936 have been examined by the staff of Louis D. Blum & Co. and the complete record of that examination follows. Particular attention, at my request, was given to a group of unpaid accounts for advertising and sales of Association publications. These have been carried forward in the list of accounts receivable, some for more than five years. They have now been written off. The effect of this is to record a deficit for the year 1936 which in fact did not accrue within that year, but during previous years.

This record may be compared with the record for 1935 by reference to page 542 of the JOURNAL for April, 1936.

There is also submitted below a membership summation for the years 1928–1936 inclusive.

Respectfully

HARRY E. JORDAN, *Secretary.*

March 24th, 1937.

Mr. Harry E. Jordan, Secretary,
American Water Works Association,
29 West 39th Street,
New York, N. Y.

Dear Sir:

Pursuant to your instructions we have made an examination of the books of account of the American Water Works Association for the year ended December 31, 1936, and as a result thereof submit herewith the following exhibits and schedule:

Exhibit "A"—Balance Sheet—December 31, 1936

Schedule 1—Investments—At Cost, December 31, 1936

Exhibit "B"—Statement of Income and Expenses for the Year Ended December 31, 1936

Exhibit "C"—Surplus Account for the Year Ended December 31, 1936

The income from dues, advertising, subscriptions and from other sources was checked and found to be substantially correct.

The expenses of your society were examined, compared with the proper authorizations therefor, and found to be properly recorded.

During the course of our examination various adjustments of your accounts were found necessary in order to bring them into agreement with information which came to our attention. Differences in the investment account, membership dues, certain accounts receivable, inventories and office equipment reserve for depreciation, were adjusted as shown in our analysis of the surplus account, Exhibit "C" of this report. Accounts receivable items, in the amount of $1,310.79 for advertising space in the journal, and $164.00 for manuals, census and index, some of which extended back four or five years, were charged off as uncollectible.

The cash balances on deposit were reconciled with statements obtained from the several depositaries. The securities on hand at December 31, 1936, were examined and found to be in order.

The accounts of your society, as reflected by the financial statements accompanying this report, are substantially on an accrual basis. This was deemed advisable in order to properly present the income and expenses for the year under review and the true net worth of the association as of December 31, 1936.

In connection with membership dues several suggestions were offered with the view of eliminating unnecessary details in the members' accounts, and possible differences which might arise in controlling balances due from members. A revision of the present card for recording membership dues, to provide for pertinent information with respect to each member, is now under consideration. We would suggest that essentially the same form of card as submitted to us be adopted, as it constitutes a desired improvement in the records of your members. It is also suggested that beginning with the year 1938, the membership dues be recorded on a cash basis, and that the accounts of members be segregated in files as "paid," "partly paid" and "unpaid." The above changes should simplify the entire accounting for membership dues.

We have had an opportunity of noting that many remittances coming into your office have not been deposited promptly. In our opinion, it is essential that remittances be entered in your books of account and deposited daily in order to safeguard against discrepancies in the accounts or "lost items."

Your attention is directed to several items appearing in Exhibit "C" of this report which are explained below:

"Income received during current period applicable to prior period" and "Expenses paid during current period applicable to prior period," amounting to $1,568.86 and $2,643.85, respectively, have been consistently entered in the secretary's books on a cash basis, and as pointed out earlier in this report, it was necessary to make the above allocations in order to reflect the income of your society during the period under review pursuant to the accrual method of accounting. Reference to the prèvious auditor's statements indicated that his report, which was also prepared on an accrual basis, gave effect to the above described items in amounts substantially in agreement with our adjustments.

"Adjustment of prior years' interest on bonds" in the amount of $55.61 was found necessary as a result of incorrect accruals of interest at the close of prior years.

Adjustment of prior years' depreciation charges in the amount of $198.17 was found necessary because the annual provision for depreciation, which was

computed on the reducing balance, was credited directly to the asset account. Our adjustment represents a correction in the depreciation reserve in order to reflect the accumulated depreciation on a straight line basis at the rate of 10 per cent per annum.

Uncollectible accounts amounting to $1,474.79 consisted of the following:

Advertising Accounts	$1,310.79
Manuals Accounts	35.00
Miscellaneous Index Accounts	110.00
Miscellaneous Census Accounts	19.00
Total	$1,474.79

"Unaccounted for difference in dues accounts" in the amount of $269.70 represents a difference between the balances due from members as disclosed by the members' cards and the general ledger controlling account; we were informed that this difference, which we are not in a position to explain, has existed for a number of years. In order to locate the difference it would be necessary to check the records of years prior to 1936 which we did not undertake due to the limited scope of our examination.

"Adjustments of investment costs" aggregating $122.43 were made to bring your records into agreement with our analysis of actual costs of the several securities in your portfolio. Our analysis indicated that commissions paid on the purchases of several securities were not included in the cost and entries representing the cost of securities sold were incorrectly stated.

We wish to express our appreciation for the kind coöperation extended to us by the several members of your staff in connection with our examination.

Very truly yours,

LOUIS D. BLUM & CO.,

Certified Public Accountants.

EXHIBIT "A"

BALANCE SHEET, DECEMBER 31, 1936

Assets

Cash in banks and on hand		$374.36
Note receivable		45.00
Accounts receivable:		
Advertising	$2,538.63	
American Public Health Association	670.91	
Royalties on manuals	42.00	
Census and index	19.00	3,270.54
Membership dues		230.72
Accrued interest on bonds		366.97

Inventories:		
Metal for index type	$250.00	
Index	198.00	
Census	34.50	
Manuals	15.00	$497.50
Office equipment	$3,624.70	
Less: Reserve for depreciation	2,203.56	1,421.14
Investments, per schedule 1—At cost		34,087.33
Total		$40,293.56

Liabilities and Surplus

Accounts payable	$2,480.67
Membership dues—Advance payments	774.02
Surplus, per exhibit "C"	37,038.87
Total	$40,293.56

EXHIBIT "B"

Statement of Income and Expenses for the Year Ended December 31, 1936

Income:		
Membership dues		$29,242.66
Advertising		16,278.00
Water Works Manufacturers' Association		7,500.00
Convention registration fees		3,915.00
Convention ticket sales		2,250.25
Subscriptions to journal		3,074.72
Miscellaneous sales of journal		438.46
One-half of profits from sales of 8th Edition of "Standard Methods of Water Analysis"		519.06
Sales of manuals		284.25
Sales of Index		107.71
Sales of reprints		859.17
Sales of Census		24.00
Royalties—Manuals		89.00
Goodell, John M. Fund		75.00
Interest income		1,619.78
Miscellaneous		2.58
Total income		$66,279.64
Expenses:		
Journal:		
Printing	$17,730.54	

Editorial and abstractors' salaries and fees	$4,621.88	
Index—1936	780.61	$23,133.03
Administrative salaries		19,015.35
Administrative office expense:		
Rent	$1,618.32	
Office supplies and expenses	2,498.49	
Membership promotion	1,052.32	
General travel expense	138.73	5,307.86
Section and division expense:		
Membership allotment, etc.	$4,568.13	
Official travel	1,604.60	6,172.73
Directors' meetings		1,939.24
General Committee expense		604.83
Sub-Committee 7A expense		318.56
Convention expense:		
General	$2,731.19	
Entertainment	6,006.09	8,737.28
Dues in other societies		460.00
Manuals		210.00
Index		46.50
Reprints		945.05
Census		15.00
Provision for depreciation of office equipment		206.30
Miscellaneous expenses		65.54
Total expenses		$67,177.27
Net loss for the year		$897.63

EXHIBIT "C"

Surplus Account for the Year Ended December 31, 1936

Balance, January 1, 1936 (Per books)		$40,655.97
Add—Credits:		
Profit realized on Chesapeake and Ohio bonds called		320.00
Income received during current period applicable to prior period:		
Profits and reimbursements received from American Public Health Association	$1,523.86	
Royalties on manuals	45.00	1,568.86

Adjustment of prior years' interest on bonds....		$55.61	
Advertising income of a prior year evidenced by a note receivable		45.00	
			$42,645.44
Deduct—Debits			
Net loss for the year, per Exhibit "B"...........		$897.63	
Expenses paid during current period applicable to prior period:			
Printing of December 1935 Journal and abstractors' fees	$1,281.68		
Printing of 1935 Index..............	711.52		
Office expense and traveling..........	162.71		
Cost of September and October 1935 reprints	189.34		
Expenses of sub-committee 7A......	113.60		
Additional section allowances.......	185.00	2,643.85	
Adjustment of prior year's depreciation charges..		198.17	
Uncollectible accounts—Advertising............		1,310.79	
Uncollectible accounts—Manuals, Census and Index		164.00	
Unaccounted for difference in dues accounts.......		269.70	
Adjustment of investment costs................		122.43	5,606.57
Balance, December 31, 1936..			$37,038.87

EXHIBIT "A", SCHEDULE 1
INVESTMENTS—AT COST, DECEMBER 31, 1936

SECURITY		PAR VALUE	DATE OF MATURITY	PURCHASE PRICE
Alabama Power Co.	4½s	$2,000.00	1967	$1,932.50
City of Los Angeles, Water Works bonds	3½s	2,000.00	1960	2,241.11
International Tel. & Tel.	5 s	3,000.00	1955	2,895.00
New York City Corporate stock	4½s	2,000.00	1956	1,990.00
New York City Corporate stock	4½s	2,000.00	1961	1,995.00
New York City Corporate stock	4½s	2,000.00	1963	1,990.00
New York City Rapid Transit Corporate stock	4½s	4,000.00	1971	3,665.50
New York Steam Corporation	5 s	4,000.00	1951	4,060.72
North American Edison	5 s	2,000.00	1969	1,915.00
Province of Ontario	4½s	2,000.00	1946	1,690.00
Province of Ontario	4 s	1,000.00	1964	732.50
Province of Ontario	5 s	3,000.00	1942	3,105.00
Province of British Columbia	4½s	1,000.00	1951	1,000.00
Southern Pacific Co.	4½s	5,000.00	1977	4,875.00
Totals		$35,000.00		$34,087.33

Membership statement for the year 1936

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	TOTAL
January 1, 1936	2,294	218	157	13	2,682
Gains:					
New Members	282	18	11		311
Reinstated	49	1	3		53
Transferred				5	5
	2,625	237	171	18	3,051
Losses:					
Resignations	71	5	6		82
Deaths	21			1	22
Suspended for Non-Payment of Dues 12/31/36	213	3	2		218
Transferred	5				5
Total Losses	310	8	8	1	327
Total December 31, 1936	2,315	229	163	17	2,724
Total January 1, 1936	2,294	218	157	13	2,682
Gain in Year 1936	21	11	6	4	42

Comparative statement—Gains and losses—Nine-year period

YEAR	NEW	REINSTATED	RESIGNATIONS	DEATHS	SUSPENDED FOR NON-PAYMENT OF DUES	GAIN OR LOSS	TOTAL MEMBERS AT END OF YEAR
1936	311	53	82	22	218	+42	2,724
1935	565	42	64	21	190	+332	2,682
1934	271	66	64	22	122	+129	2,350
1933	168	56	132	27	234	−169	2,221
1932	117	22	141	28	297	−327	2,390
1931	203	22	98	25	216	−114	2,717
1930	501	39	95	26	134	+285	2,831
1929	314	25	94	24	130	+91	2,547
1928	203	36	86	13	126	+14	2,456
Totals 9-year period	2,653	361	856	208	1,667	+283	

DIRECTORY OF OFFICERS AND COMMITTEES OF THE AMERICAN WATER WORKS ASSOCIATION

This directory, including the committees of the Association, is here published for the second time in the JOURNAL. As explained in the Membership List, which was distributed as a supplement to the September 1936 JOURNAL, it is planned hereafter to publish this directory once or twice each year as may be desirable. The listing of officers is here repeated from the front of the JOURNAL in order to place it on record in the bound portion of the JOURNAL.

The listings here given are corrected up to May 1, 1937.

The addresses of officers (and of committee members if they are members of the Association) may be obtained from the printed Membership List of the Association, September, 1936. For further information regarding the committees or their personnel refer to the office of the Secretary of the Association, 29 West 39th Street, New York, N. Y.

OFFICERS

*WILLIAM W. HURLBUT	*President*	June 11, '36 to June 10, '37
*WILLIAM W. BRUSH	*Treasurer*	June 28, '29 to June 10, '37
HARRY E. JORDAN		*Secretary*
BEEKMAN C. LITTLE		*Secretary Emeritus*

DIRECTORS

*FRANK A. BARBOUR	*ex-officio (past president)*	May 5, '32 to '37
*WILLIAM W. BRUSH	*ex-officio (treasurer)*	June 28, '29 to '37
*EUGENE F. DUGGER	*Virginia Section*	June 7, '34 to '37
LINN H. ENSLOW	*ex-officio (Publication Comm.)*	May 9, '35 to '37
*NORMAN J. HOWARD	*Canadian Section*	June 7, '34 to '37
*WILLIAM C. MABEE	*Indiana Section*	Apr. 8, '36 to '37
*GUY C. NORTHROP	*W. W. Manufacturers' Ass'n*	Jan. 16, '36 to '37
*L. C. OSBORN	*Rocky Mountain Section*	June 7, '34 to '37
MALCOLM PIRNIE	*ex-officio (W. W. Pr. Comm.)*	June 6, '30 to '37
*LEON A. SMITH	*Wisconsin Section*	June 7, '34 to '37
*M. F. TRICE	*North Carolina Section*	June 7, '34 to '37
*W. H. WEIR	*Southeastern Section*	June 7, '34 to '37
LEWIS V. CARPENTER	*Central States Section*	May 9, '35 to '38
W. P. HUGHES	*Pacific Northwest Section*	May 9, '35 to '38
WILLIAM W. HURLBUT	*ex-officio (president)*	June 15, '33 to '38

JOHN A. KIENLE	*W. W. Manufacturers' Ass'n*	Jan. 16, '36 to '38
THEODORE A. LEISEN	*Missouri Valley Section*	May 9, '35 to '38
REEVES J. NEWSOM	*New York Section*	May 9, '35 to '38
WILLIAM J. ORCHARD	*New Jersey Section*	Jan. 16, '36 to '38
JOHN J. QUINN	*Kentucky-Tennessee Section*	May 9, '35 to '38
ROBERT S. WESTON	*New England Section*	May 9, '35 to '38
HAROLD E. BABBITT	*Illinois Section*	June 11, '36 to '39
CHARLES H. BECKER	*Four-States Section*	June 11, '36 to '39
A. P. BLACK	*Florida Section*	June 11, '36 to '39
NELSON A. ECKART	*California Section*	June 11, '36 to '39
DENIS F. O'BRIEN	*W. W. Manufacturers' Ass'n*	June 6, '30 to '39
JOSEPH M. SCHMIT	*Montana Section*	June 11, '36 to '39
LEONARD N. THOMPSON	*Minnesota Section*	June 11, '36 to '39
JOHN B. WINDER	*Southwest Section*	June 11, '36 to '39

Terms of office expire on the last day of the annual convention. The exact date is not known until the date of the convention is fixed. In the cases of officers whose terms expire in 1937 the date is June 10.

*** New officers who have been chosen to take office on June 10, 1937, are as follows:**

EUGENE F. DUGGER	*as President, succeeding* WILLIAM W. HURLBUT
WILLIAM W. HURLBUT	*as Past President, succeeding* FRANK A. BARBOUR
WILLIAM W. BRUSH	*as Treasurer, succeeding himself*
MARSDEN C. SMITH	*as Director, succeeding* EUGENE F. DUGGER
ALBERT E. BERRY	*as Director, succeeding* NORMAN J. HOWARD
H. A. DILL	*as Director, succeeding* WILLIAM C. MABEE
CHESTER S. TRUMAN	*as Director, succeeding* L. C. OSBORN
ARTHUR H. MILLER	*as Director, succeeding* LEON A. SMITH
PAUL W. FRISK	*as Director, succeeding* M. F. TRICE
J. K. MARQUIS	*as Director, succeeding* W. H. WEIR
WILLARD T. CHEVALIER	*as Director, succeeding* GUY C. NORTHROP

STAFF

PERCY S. WILSON	*Technical Assistant Secretary*
WILBUR M. NIESLEY	*Administrative Assistant Secretary*
MURIEL MEISNER	
GERTRUDE UHR	

OFFICERS OF THE DIVISIONS

FINANCE AND ACCOUNTING DIVISION

HAL F. SMITH	*Chairman*	June 11, '36 to June 10, '37
JACOB SCHWARTZ	*Vice Chairman*	June 11, '36 to June 10, '37
CHARLES J. ALFKE	*Secretary-Treasurer*	May 9, '35 to June 10, '37
LOUIS D. BLUM	*Director*	June 11, '36 to June 10, '37
JOHN H. MURDOCH, JR	*Director*	May 9, '35 to June 10, '37

PLANT MANAGEMENT AND OPERATION DIVISION

W. Victor Weir	*Chairman*	June 11, '36 to June 10, '37
Thomas J. Skinker	*Vice Chairman*	June 11, '36 to June 10, '37
Percy S. Wilson	*Secretary-Treasurer*	June 11, '36 to June 10, '37
William W. Hurlbut	*Director*	June 11, '36 to June 10, '37
R. B. Simms	*Director*	June 11, '36 to June 10, '37

WATER PURIFICATION DIVISION

Carl J. Lauter	*Chairman*	June 11, '36 to June 10, '37
William M. Wallace	*Vice Chairman*	June 11, '36 to June 10, '37
Charles R. Cox	*Secretary-Treasurer*	June 7, '34 to June 10, '37
Albert E. Berry	*Member Exec. Comm.*	June 11, '36 to June 10, '37
Mathew M. Braidech	*Member Exec. Comm*	May 9, '35 to June 10, '37
Charles G. Hyde	*Member Exec. Comm.*	June 11, '36 to June 10, '37

OFFICERS OF THE SECTIONS

CALIFORNIA SECTION

Robert F. Brown, *Chairman*
James E. Phillips, *Vice Chairman*
Carl M. Hoskinson, *Secy.-Treas.*
Nelson A. Eckart, *Ass'n. Dir.*
J. R. Barker, *Exec. Comm.*
George W. Hawley, *Exec. Comm.*
John S. Longwell, *Exec. Comm.*
Fred S. Porter, *Exec. Comm.*
Harry Reinhardt, *Exec. Comm.*
H. A. Van Norman, *Exec. Comm.*

CANADIAN SECTION

E. V. Buchanan, *Chairman*
Albert E. Berry, *Secy.-Treas.*
Norman J. Howard, *Ass'n. Dir.*
J. J. Salmond, *Manufacturers' Repr.*
F. P. Adams, *Past Chairman*
C. E. Brown, *Trustee*
C. J. DesBaillets, *Trustee*
A. B. Manson, *Trustee*
L. G. McNeice, *Trustee*
A. D. Stalker, *Trustee*
G. H. Strickland, *Trustee*

CENTRAL STATES SECTION

Roberts Hulbert, *Chairman*
E. C. Trax, *Vice Chairman*
H. Lloyd Nelson, *Secy.-Treas.*
Lewis V. Carpenter, *Ass'n. Dir.*
E. A. Johnson, *Trustee*
W. R. LaDue, *Trustee*
T. L. Young, *Trustee*

FLORIDA SECTION

Donald S. Wallace, *Chairman*
Thomas M. Lowe, *Vice Chairman*
J. R. Hoy, *Secy.-Treas.*
A. P. Black, *Ass'n. Dir.*
G. F. Catlett, *Trustee*
J. C. Chalfant, *Trustee*
Keith R. Chinn, *Trustee*
Francis R. Mills, *Trustee*
Raymond G. Ridgley, *Trustee*
J. R. Tanner, *Trustee*

FOUR-STATES SECTION

HARRY M. FREEBURN, *Chairman* — CARL J. LAUTER, *Vice Chairman*
CARL A. HECHMER, *Secy.-Treas.* — CHARLES H. BECKER, *Ass'n. Dir.*
EZRA B. WHITMAN, *Past Chairman* — I. M. GLACE, *Trustee*
EDWARD S. HOPKINS, *Trustee* — GEORGE R. TAYLOR, *Trustee*
ABEL WOLMAN, *Trustee*

ILLINOIS SECTION

FRANK C. AMSBARY, JR., *Chairman* — RAY CROZIER, *Vice-Chairman*
W. D. GERBER, *Secy.-Treas.* — H. E. BABBITT, *Ass'n. Dir.*
C. H. SPAULDING, *Past Chairman* — F. G. GORDON, *Trustee*
G. B. PRINDLE, *Trustee*

INDIANA SECTION

JOHN L. FORD, *Chairman* — PAUL C. LAUX, *Vice Chairman*
JOHN A. BRUHN, *Secy.-Treas.* — WILLIAM C. MABEE, *Ass'n. Dir.*
B. A. POOLE, *Past Chairman* — W. A. OEFFLER, *Asst. Secy.-Treas.*

KENTUCKY-TENNESSEE SECTION

E. E. JACOBSON, *Chairman* — C. M. MCCORD, *Vice Chairman*
HOWARD D. SCHMIDT, *Secy.-Treas.* — JOHN J. QUINN, *Ass'n. Dir.*
ROY J. MORTON, *Past Chairman* — HALL ARNOLD, *Director*
H. C. BRISTOL, *Director*

MINNESOTA SECTION

ROSS A. THUMA, *Chairman* — FELIX SELIGMAN, *Vice Chairman*
R. M. FINCH, *Secy.-Treas.* — LEONARD N. THOMPSON, *Ass'n. Dir.*
EDWIN M. GRIME, *Trustee* — A. C. JANZIG, *Trustee*
EUGENE SCHWARZ, *Trustee*

MISSOURI VALLEY SECTION

N. T. VEATCH, JR., *Chairman* — DALE L. MAFFITT, *Vice Chairman*
EARLE L. WATERMAN, *Secy.-Treas.* — THEODORE A. LEISEN, *Ass'n. Dir.*
W. V. WEIR, *Director, Missouri* — J. R. HENRY, *Director, Nebraska*
WALTER W. MOLIS, *Director, Iowa* — W. W. TOWNE, *Director, S. Dakota*
BERNARD L. ULRICH, *Director, Kansas*

MONTANA SECTION

ROY N. ARNOLD, *Chairman* — GEORGE ATKINSON, *Vice Chairman*
H. B. FOOTE, *Secy.-Treas.* — JOSEPH M. SCHMIT, *Ass'n. Dir.*
WADE PLUMMER, *Trustee* — A. J. ROBERTS, *Trustee*

NEW ENGLAND SECTION

WARREN J. SCOTT, *Chairman* — SIDNEY S. ANTHONY, *Vice Chairman*
SAMUEL M. ELLSWORTH, *Secy.-Treas.* — ROBERT SPURR WESTON, *Ass'n. Dir.*
HAROLD W. GRISWOLD, *Trustee* — FRANK A. MARSTON, *Trustee*

NEW JERSEY SECTION

Samuel F. Newkirk, Jr., *Chairman* | C. D. Moon, *Vice Chairman*
Percy S. Wilson, *Secy.-Treas.* | William J. Orchard, *Ass'n. Dir.*
J. A. Carr, *Trustee* | William R. Conard, *Trustee*
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NEW YORK SECTION

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Rollo K. Blanchard, *Secy.-Treas.* | Reeves J. Newsom, *Ass'n. Dir.*
Charles R. Cox, *Trustee* | William T. Field, *Trustee*
Franklin Henshaw, *Trustee*

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A. R. Hollett, *Secy.-Treas.* | M. F. Trice, *Ass'n. Dir.*
C. E. Rhyne, *Past President*

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Fred Merryfield, *Secy.-Treas.* | W. P. Hughes, *Ass'n. Dir.*
John W. Cunningham, *Trustee* | Harold D. Fowler, *Trustee*

ROCKY MOUNTAIN SECTION

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B. V. Howe, *Secy.-Treas.* | L. C. Osborn, *Ass'n. Dir.*
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Ben Davis, *Trustee* | J. P. Soderstrum, *Trustee*
O. B. Sumner, *Trustee*

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D. Rhett Pringle, *Chairman* | C. P. Townsend, *Vice Chairman*
W. H. Weir, *Secy.-Treas.* | W. H. Weir, *Ass'n. Dir.*
F. G. Crow, *Trustee* | J. L. Hawkins, *Trustee*
M. G. Stewart, *Trustee* | T. E. P. Woodward, *Trustee*

SOUTHWEST SECTION

Henry E. Nunn, *Chairman* | Thomas L. Amiss, *Vice Chairman*
Lewis A. Quigley, *Secy.-Treas.* | John B. Winder, *Ass'n. Dir.*
George J. Rohan, *Past Chairman* | R. H. Brooks, *Trustee, Louisiana*
A. M. Brenneke, *Trustee, Texas* | L. H. Scott, *Trustee, Oklahoma*
L. M. Rebsamen, *Trustee, Arkansas*

VIRGINIA SECTION

A. L. Meisel, *Chairman* | Hugh B. Rice, *Vice Chairman*
H. W. Snidow, *Secretary* | Eugene F. Dugger, *Ass'n. Dir.*
E. C. Meredith, *Treasurer* | S. L. Williamson, *Past Chairman*
Howard A. Johnson, *Trustee* | Marsden C. Smith, *Trustee*

WISCONSIN SECTION

C. S. GRUETZMACHER, *Chairman*
WILLIAM U. GALLAHER, *Vice Chairman*
LEON A. SMITH, *Secy.-Treas.*
LEON A. SMITH, *Ass'n. Dir.*
A. P. KURANZ, *Past Chairman*
W. C. STAEFFLER, *Director*

COMMITTEES

GENERAL COMMITTEES

EXECUTIVE COMMITTEE OF THE DIRECTORS

WILLIAM W. HURLBUT, *chairman*
FRANK A. BARBOUR
WILLIAM W. BRUSH
REEVES J. NEWSOM
DENIS F. O'BRIEN

COMMITTEE ON WATER WORKS PRACTICE

MALCOLM PIRNIE, *chairman*
FRANK A. BARBOUR
ROLLO K. BLANCHARD
FRED G. CUNNINGHAM
WILFORD W. DEBERARD
JAMES E. GIBSON
ARTHUR E. GORMAN
GEORGE W. PRACY
A. U. SANDERSON
ABEL WOLMAN

This committee is charged with general direction of all technical committee work of the Association and its Divisions and Sections, the establishment of all professional or technical standards and the preparation of material for the Water Works Practice Manual and its supplements. The sub-committees under this committee are listed under a special heading on a later page.

PUBLICATION COMMITTEE

LINN H. ENSLOW, *chairman*
ELSON T. KILLAM, *vice chairman*
PERCY S. WILSON, *secretary*
FRANK A. BARBOUR
ALBERT E. BERRY
ROLLO K. BLANCHARD
WILLIAM W. BRUSH
LEWIS V. CARPENTER
WILFORD W. DEBERARD
G. GALE DIXON
ROSS L. DOBBIN
EUGENE F. DUGGER
CARL A. HECHMER
WILLIAM W. HURLBUT
J. ARTHUR JENSEN
HARRY E. JORDAN
CARL J. LAUTER
SAMUEL B. MORRIS
BEN S. MORROW
REEVES J. NEWSOM
WALTER A. PEIRCE
MALCOLM PIRNIE
HAL F. SMITH
M. F. TRICE
NATHAN T. VEATCH, JR.
W. H. WEIR
W. VICTOR WEIR
JOHN B. WINDER
ABEL WOLMAN

This committee plans the annual convention program and has general control of all publications.

PUBLICATION EXECUTIVE SUB-COMMITTEE

Harry E. Jordan, *chairman*
William W. Brush
Linn H. Enslow
Reeves J. Newsom
William J. Orchard

This sub-committee has direct authority and power over the editing and business management of all of the Association's publications.

CONSTITUTION AND BY-LAWS

Ross L. Dobbin, *chairman*
Eugene F. Dugger
George H. Fenkell
James E. Gibson
Harry E. Jordan

This committee considers and gives recommendations as to desired amendments to the Constitution or By-Laws of the Association. It also passes upon all new By-Laws, or amendments to the By-Laws, of Divisions and Sections of the Association.

HONORARY MEMBERSHIP

William W. Hurlbut, *chairman*
Frank A. Barbour
Harry E. Jordan

This is a committee of the Directors. It makes recommendations for election to Honorary Membership in the Association. It usually is made up of the President and the last two past presidents.

THE JOHN M. DIVEN MEMORIAL MEDAL

Malcolm Pirnie, *chairman*
Albert E. Berry
Louis D. Blum
Linn H. Enslow
William W. Hurlbut

This committee makes recommendation to the Directors as to the award of the Diven medal. It usually consists of the chairmen of the Water Works Practice and Publication Committees and the Past Chairmen of each of the three Divisions.

THE JOHN M. GOODELL PRIZE

Samuel B. Morris, *chairman*
E. Sherman Chase
Earle L. Waterman

This committee makes recommendation to the Directors as to the award of the Goodell prize. Each member serves three years.

GEORGE W. FULLER MEMORIAL

Arthur E. Gorman, *chairman*
Willard T. Chevalier
Ralph W. Lawton
Arthur D. Weston
Thomas H. Wiggin

This is a temporary committee formed for the purpose of recommending the form of a memorial to be established in memory of Past President George W. Fuller.

CONVENTION PLACE

Representing the A. W. W. A.	*Representing the W. W. Mfrs. Assn.*
HARRY E. JORDAN, *chairman*	JOHN A. KIENLE
PAUL HANSEN	DENIS F. O'BRIEN
W. H. WEIR	MARTIN F. TIERNAN

This committee makes recommendation to the Directors as to the location and date of the Association's annual convention.

CONVENTION MANAGEMENT

Representing the A. W. W. A.	*Representing the W. W. Mfrs. Assn.*
ROLLO K. BLANCHARD, *chairman*	CLINTON INGLEE
WILLIAM W. BRUSH	WILLIAM J. ORCHARD
ALAN D. DRAKE	

Ex-officio

WILLIAM W. HURLBUT, *Pres., A. W. W. A.*
HARRY E. JORDAN, *Secy., A. W. W. A.*
LINN H. ENSLOW, *Chr. Publ. Comm.*
EDWARD T. FISHWICK, *Pres., W. W. Mfrs. Assn.*
JOHN A. KIENLE, *Secy., W. W. Mfrs. Assn.*

This committee is in charge of the management of all details of the Association's annual convention, except the program and the choice of location and date.

PUBLICITY AND CONVENTION ATTENDANCE

CHARLES H. EASTWOOD, *chairman*	JOSEPH M. WAFER, *Vice-Chairman*
FRANK C. AMSBARY, JR.	E. J. BUTTENHEIM
WILLARD T. CHEVALIER	L. H. ENSLOW
W. A. HARDENBERGH	KARL M. MANN
ALEX. L. MCPHAIL	JAMES J. SALMOND
W. D. STALKER	FRANK O. WALLENE

The purpose of this committee is to promote attendance at the annual convention and to arrange local and general publicity for the convention and its speakers.

MEMBERSHIP

CHARLES H. EASTWOOD, *chairman*

This committee is developing and putting into effect a permanent and continuous system to increase Association membership.

GENERAL POLICY

Frank A. Barbour, *chairman*
George H. Fenkell
William W. Hurlbut
Denis F. O'Brien
Ross L. Dobbin
Eugene F. Dugger
Harry E. Jordan
Malcolm Pirnie

This is a temporary committee charged with the duty of formulating policies of the Association with regard to the field and extent of its activities, the development of Local Sections and a number of other broadly related and fundamental subjects. It is empowered to reorganize the headquarters staff to effectuate these policies.

SECTION AFFAIRS

Lewis V. Carpenter, *chairman*
Wilford W. DeBerard
Eugene F. Dugger
Rollo K. Blanchard
Ross L. Dobbin

The purpose of this committee is to study problems arising in the conduct of the activities of the Sections, to recommend procedure and assist in securing suitable and uniform action on such subjects.

WATER WORKS SHORT SCHOOLS AND LICENSING OF WATER WORKS EMPLOYEES

Lewis V. Carpenter, *chairman*
William U. Gallaher
C. A. Holmquist
William W. Brush
Ray F. Goudey
Paul Weir

This committee has been formed for the purpose of studying the action taken and contemplated in various states to license water works employees, and to assist in securing beneficial action along these lines.

FEDERAL INCOME TAX

William W. Brush, *chairman*
William W. Hurlbut
Eugene F. Dugger

This committee is authorized to consider the subject of Federal Income Taxation of the salaries of Municipal Water Works Employees and to take such action as may be considered advisable regarding it.

NATIONAL WATER POLICY

Abel Wolman, *chairman*
Theodore A. Leisen
Howard S. Morse
Louis R. Howson
Samuel B. Morris

This committee is charged with the duty of observing the plans and actions of the Federal Government's National Resources Board and its allied groups, and of representing the Association in any actions on subjects being considered by them.

SOCIAL SECURITY LEGISLATION

DALE L. MAFFITT, *chairman*

This committee, the organization of which was authorized in January, 1937, was formed for the purpose of following developments in Social Security Legislation and of keeping the Association informed on the subject.

WATER WORKS PRACTICE SUB-COMMITTEES

GENERAL

UNIFORM MARKING OF FIRE HYDRANTS

STEPHEN H. TAYLOR, *chairman*
WILLIAM W. BRUSH
ROSS L. DOBBIN
HENRY E. HALPIN
GEORGE W. PRACY

This committee's purpose is to recommend a uniform system of marking fire hydrants, by means of color, to indicate their discharging capacity. The committee is working in conjunction with the Maine Water Utilities Association, the New England Water Works Association, and the fire insurance and prevention organizations in this work. A final report was presented and discussed at the 1936 annual convention and published in the JOURNAL, April 1937, page 449.

CHEMICAL HAZARDS IN WATER WORKS PLANTS

MARSDEN C. SMITH, *chairman*
LINN H. ENSLOW
GEORGE H. FENKELL
H. H. GERSTEIN
ARTHUR E. GORMAN
RAY F. GOUDEY
FRANK E. HALE
L. L. HEDGEPETH
NORMAN J. HOWARD
HAROLD S. HUTTON
WILLARD C. LAWRENCE
WINFIELD S. MAHLIE

This committee was organized to report on the best methods of handling chemicals used in water purification in order to avoid injury to personnel or damage to plant from their use, and to recommend methods of meeting difficulties which may arise in the handling of these chemicals. This committee's report on chlorine was published in the JOURNAL, September, 1935, page 1225. A second report, on ammonia, was presented at the 1936 annual convention and published in the JOURNAL, November, 1936, page 1772. Further work is contemplated.

ELECTROLYSIS AND ELECTRICAL INTERFERENCE

CHARLES F. MEYERHERM, *secretary*
M. WARREN COWLES
EDWARD E. MINOR

This committee has been working for a number of years on problems in connection with the electrolysis of water pipes, and recently in particular, on questions concerning the use of water pipes as a means of grounding electrical systems. Partly as a result of the activity of this committee there was recently

organized the American Research Committee on Grounding, listed on a later page under Joint Committees.

PIPE LINE FRICTION COEFFICIENTS

Clinton L. Bogert, *chairman*	H. G. Acres
James E. Gibson	Reeves J. Newsom
Fred C. Scobey	Thomas J. Skinker
Robert Spurr Weston	Thomas F. Wolfe

Established at the suggestion of the New England Water Works Association this committee's purpose is to coöperate with that association in the preparation of a report covering a wider geographic field than was covered in the report of the New England committee. This committee is not to carry on any independent research but will only review existing data.

HISTORY OF WATER PURIFICATION

M. N. Baker, *chairman*

Mr. Baker is conducting an extensive research in this country and abroad in the preparation of a record of the developments which have led up to modern water treatment. This committee was formerly listed as a sub-committee under Water Works Practice Committee 5.

COMMITTEES ON THE MANUAL

These committees were arranged and organized in order to prepare revisions and additions to the Manual of Water Works Practice. As the projects undertaken by these committees are completed they will probably be published separately in order to make them available at once.

COMMITTEE 1—BASIC DATA

Elson T. Killam, *chairman*	Moses N. Baker
Albert E. Berry	Charles R. Cox
Nathan B. Jacobs	Frank C. Jordan
Samuel B. Morris	

To consider and recommend procedure in the development of a program for the collection of water works data and statistics, and particularly to coöperate with the U. S. National Resources Committee in their work on the same subject.

COMMITTEE 2—SURFACE WATER ALLOCATION

COMMITTEE 3—SURFACE WATER COLLECTION

COMMITTEE 4—GROUND WATER COLLECTION

Daniel W. Mead, *chairman*

COMMITTEE 5—QUALITY AND TREATMENT

PAUL HANSEN, *chairman* LEWIS V. CARPENTER, *vice chairman*

The combined work of all of the former divisions of this committee is now being prepared for publication as a separate book on Quality and Treatment of Water.

COMMITTEE 6—POWER AND PUMPING

FRED G. CUNNINGHAM, *chairman* F. G. GORDON
WILLIAM C. RUDD

COMMITTEE 7—TRANSMISSION AND DISTRIBUTION

G. GALE DIXON, *chairman*

This committee has submitted a tentative specification for Gate Valves, published in the JOURNAL, March, 1937, page 408, which will supersede the present standard specification when adopted.

Sub-Committee 7-A—Steel Plate Pipe

WILLIAM W. HURLBUT, *chairman* FRANK A. BARBOUR
WILLIAM W. BRUSH GEORGE H. FENKELL
FRED M. RANDLETT JOHN F. SKINNER
THOMAS H. WIGGIN

This committee is preparing standard specifications for steel plate pipe, including both riveted and welded types, and coatings. The work on welded construction is being done in collaboration with sub-committee 7-W.

Advisory Sub-Committee under Sub-Committee 7-A

LAWRENCE F. ALLAN.......... *Repr. Canadian Sect.*
W. L. MCFAUL.......... *Repr. Canadian Sect.*
EDWARD M. PROCTOR.......... *Repr. Canadian Sect.*
A. U. SANDERSON.......... *Repr. Canadian Sect.*
RALPH W. REYNOLDS.......... *Repr. Florida Sect.*
SETH M. VAN LOAN.......... *Repr. Four States Sect.*
GEORGE T. HORTON.......... *Repr. Illinois Sect.*
THEODORE A. LEISEN.......... *Repr. Missouri Valley Sect.*
THOMAS J. SKINKER.......... *Repr. Missouri Valley Sect.*
HAROLD W. GRISWOLD.......... *Repr. New England Sect.*
WILLIAM R. CONARD.......... *Repr. New Jersey Sect.*
W. A. KUNIGK.......... *Repr. Pacific Northwest Sect.*
JOHN W. CUNNINGHAM.......... *Repr. Pacific Northwest Sect.*
DWIGHT D. GROSS.......... *Repr. Rocky Mountain Sect.*
JOHN J. WILSON.......... *Repr. Rocky Mountain Sect.*
A. CLINTON DECKER.......... *Repr. Southeastern Sect.*
W. S. TOMLINSON.......... *Repr. Southeastern Sect.*

Albert R. Davis..Repr. Southwest Sect.
Frank M. Murphy..Repr. Southwest Sect.
Richard F. Wagner..Repr. Virginia Sect.

Sub-Committee 7-B—Reinforced Concrete Pipe

Sub-Committee 7-C—Cast Iron Pipe

The work which would ordinarily be undertaken by this sub-committee is being carried on by Sectional Committee A21, on Specifications for Cast Iron Pipe, Thomas H. Wiggin, Chairman. This is a joint committee organized under the procedure established by the American Standards Association and on which the American Water Works Association is represented. This committee is listed under Joint Committees.

Sub-Committee 7-D—Laying Cast Iron Pipe

William C. Mabee, *chairman*
E. T. Cranch
Samuel E. Killam
B. A. Poole
William M. Rapp
George G. Routledge
J. B. Winder
Clinton L. Bogert
William W. Hurlbut
H. Lloyd Nelson
George W. Pracy
Ralph W. Reynolds
Thomas J. Skinker
Frank Y. Dorrance

This committee is preparing standard specifications for the laying of cast iron pipe.

Sub-Committee 7-E—Valves, Sluice Gates and Fire Hydrants

William R. Conard, *chairman*
Harold W. Griswold
Frank H. Stephenson
William Flannery
J. Arthur Jensen

This committee has submitted a tentative specification for Fire Hydrants, published in the Journal, April, 1937, page 451, which will supersede the present standard specification when adopted.

Sub-Committee 7-F—Meters

James E. Gibson, *chairman*
George W. Pracy
Seth M. Van Loan
Leonard A. Day
Stephen H. Taylor

Sub-Committee 7-G—Location Records and Maintenance of Mains and Services

Albert S. Hibbs, *chairman*
Thomas J. Skinker
Anthony R. O'Reilly

Sub-Committee 7-H—Steel Standpipes and Elevated Tanks

LOUIS R. HOWSON, *chairman* NATHAN T. VEATCH, JR.

The new specifications issued by this committee were published in the JOURNAL in November, 1935. This committee, working in collaboration with Sub-Committee 7-W, is now proceeding to amplify these specifications to include welded construction.

Sub-Committee 7-J—Distribution Reservoirs

Sub-Committee 7-K—Water Consumption

Sub-Committee 7-L—Fire Prevention and Protection

JOHN H. MURDOCH, JR., *chairman*
PHILIP BURGESS
THAD M. ERWIN
L. W. HELMREICH
FRANK C. JORDAN
CALEB MILLS SAVILLE
WILLIAM STORRIE
J. WALTER ACKERMAN
CARLTON E. DAVIS
HARRY U. FULLER
LOUIS R. HOWSON
DALE L. MAFFITT
LEON A. SMITH

This committee was re-established in January 1937 and charged particularly with a study of questions concerning the use of public water supplies for private fire protection.

Sub-Committee 7-M—Hydraulics of Distribution System

Sub-Committee 7-S—Service Line Materials

WALTER A. PEIRCE, *chairman*
PAUL D. COOK
DWIGHT D. GROSS
C. D. MOON
REEVES J. NEWSOM
GEORGE W. PRACY
F. ALBERT SCHAEFER
FRANK C. AMSBARY, JR.
JOHN C. DETWEILER
E. E. JACOBSON
R. H. MARTINDALE
H. V. PEDERSEN
EDWARD H. RUEHL
W. E. SWARTZ

This committee is charged with the review, approval and publication of specifications for copper, iron (wrought or cast) lead, etc. tubing or pipe in sizes and weights suitable for water service lines.

The committee may also, to a limited extent, review and summarize current methods of installation of service lines.

Sub-Committee 7-T—Transite Pipe

CLARENCE R. KNOWLES, *chairman*
WILLIAM D. HURST
HAROLD B. STEWART
CLARENCE GOLDSMITH
C. A. MCGINNIS

A report of this committee appears in the JOURNAL, May, 1937.

Sub-Committee 7-W—Welding of Steel Standpipes, Elevated Tanks and Pipe

LOUIS R. HOWSON, *chairman*	H. O. HILL
GEORGE T. HORTON	J. O. JACKSON
J. P. SCHWADA	

This committee has been organized in order to collaborate with sub-committees 7-A and 7-H in extending the work of those two committees to include welded construction.

Committee 8—Cross Connections

E. SHERMAN CHASE, *chairman*	J. WALTER ACKERMAN
O. E. BROWNELL	M. W. COWLES
JOEL I. CONNOLLY	F. M. DAWSON
EARL DEVENDORF	H. E. HALPIN
J. A. JENSEN	W. SCOTT JOHNSON
R. E. TARBETT	W. J. SCOTT

WATER PURIFICATION DIVISION COMMITTEES

SPECIFICATIONS AND TESTS FOR WATER PURIFICATION CHEMICALS

MATHEW M. BRAIDECH, *chairman*	R. C. BARDWELL
WILLIAM U. GALLAHER	GILBERT L. KELSO
WARREN A. KRAMER	WINFIELD S. MAHLIE
GEORGE R. SPALDING	

This committee is preparing standard specifications for twenty-six of the chemicals used in water purification processes. See the JOURNAL, April, 1934, page 532, for progress report.

SPECIFICATIONS AND TESTS FOR POWDERED ACTIVATED CARBONS

MATHEW M. BRAIDECH, *chairman*	LLOYD C. BILLINGS
F. WELLINGTON GILCREAS	NEIL KERSHAW
R. D. SCOTT	GEORGE R. SPALDING

Last progress report of this committee was presented at the Los Angeles convention, June, 1936.

METHODS OF TESTING ZEOLITES

CHARLES P. HOOVER, *chairman*	JACK J. HINMAN, JR.
SHEPPARD T. POWELL	

This committee's last progress report was published in the JOURNAL, September, 1935, page 1178.

METHODS OF DETERMINING FLUORIDES

A. P. BLACK, *chairman*	W. D. COLLINS
RAY F. GOUDEY	M. STARR NICHOLS
R. D. SCOTT	GLADYS SWOPE
W. V. UPTON	L. V. WILCOX

This committee has been formed in order to perfect present laboratory methods of determining the fluoride content of water including particularly a comparative study of the Sanchis and the Elvove methods. Organized since the 1936 annual convention.

STUDY OF CHLORINE-AMMONIA TREATMENT

F. Wellington Gilcreas, *chairman*
Kenneth W. Brown
H. H. Gerstein
Roberts Hulbert
J. F. T. Berliner
Harry A. Faber
Attmore E. Griffin

Organized since the 1936 annual convention

JOINT COMMITTEES WITH OTHER ORGANIZATIONS

JOINT EDITORIAL COMMITTEE ON STANDARD METHODS FOR THE EXAMINATION OF WATER AND SEWAGE

American Public Health Association

American Water Works Association

Representatives of A. W. W. A.:

Harry E. Jordan, *chairman*
Harold A. Leverin
William D. Hatfield

Representatives of A. P. H. A.:

Arthur M. Buswell
John F. Norton
Sheppard T. Powell

This committee performs the editorial work and makes all arrangements for the publication of the book "Standard Methods for the Examination of Water and Sewage." An eighth edition of this book has just been issued.

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

American Boiler Manufacturers Association

Association of American Railroads (formerly Amer. Ry. Engineering Assn.)

American Society of Mechanical Engineers

American Society for Testing Materials

American Water Works Association

Edison Electric Institute

Representatives of A. W. W. A.:

Harry E. Jordan
Sheppard T. Powell

The general chairman of this joint committee is C. H. Fellows, Research Department, The Detroit Edison Co., 2000 Second Ave., Detroit, Michigan. The secretary is J. B. Romer, Chief Chemist, The Babcock & Wilcox Co., Barberton, Ohio. An executive sub-committee and nine technical subcommittees have been arranged.

AMERICAN RESEARCH COMMITTEE ON GROUNDING

American Water Works Association

Edison Electric Institute

Representatives of A. W. W. A.:

M. WARREN COWLES
EDWARD E. MINOR
CHARLES F. MEYERHERM

This committee has been formed in order to investigate and report upon the various questions involved in the grounding of electrical circuits on water, gas and drainage piping. The general chairman of this committee is H. S. Warren, Bell Telephone Laboratories, 463 West Street, New York, N. Y. The secretary-treasurer is C. F. Meyerherm. The complete personnel of this committee may be obtained upon inquiry to the Secretary of the A. W. W. A.

WATER WORKS TERMS

American Public Health Association

American Society of Civil Engineers

American Water Works Association

THORNDIKE SAVILLE, *General Chairman*

Representatives of A. P. H. A.:

EARLE B. PHELPS, *sub-chairman*
SOL PINCUS
RALPH E. TARBETT

Representatives of A. S. C. E.:

H. BURDETT CLEVELAND, *sub-chairman*
O. E. BROWNELL
JOHN B. HAWLEY

Representatives of A. W. W. A.:

THORNDIKE SAVILLE, *sub-chairman*
HAROLD E. BABBITT
SAMUEL B. MORRIS

This committee has been formed to recommend usage as to the definition and meaning of various terms used in the practice of water works engineering and operation.

WATER WORKS ACCOUNTING MANUAL

A Joint Enterprise of

American Water Works Association

Municipal Finance Officers' Association

Representative of A. W. W. A.:

HAL F. SMITH

Representative of M. F. O. A.:

CARL H. CHATTERS

Chief of Technical Staff:

CHARLES T. SWEENEY

A. W. W. A. Review and Recommendation Committee

J. J. SHARON . . . . . *Repr. California Section*
F. P. ADAMS . . . . . *Repr. Canadian Section*
E. E. BANKSON . . . . . *Repr. Central States Section*
R. W. REYNOLDS . . . . . *Repr. Florida Section*
C. A. HECHMER . . . . . *Repr. Four States Section*
W. R. GELSTON . . . . . *Repr. Illinois Section*
E. C. SCHWIER . . . . . *Repr. Indiana Section*
R. L. LAWRENCE . . . . . *Repr. Kentucky-Tennessee Section*
JOHN C. FLANAGAN . . . . . *Repr. Minnesota Section*
A. L. HEWETT . . . . . *Repr. Montana Section*
T. L. BRISTOL . . . . . *Repr. New England Section*
C. J. ALFKE . . . . . *Repr. New Jersey Section*
ALEXANDER RUSSELL . . . . . *Repr. New York Section*
R. A. THOMAS . . . . . *Repr. North Carolina Section*
D. L. MAFFITT . . . . . *Repr. Missouri Valley Section*
G. B. SCHUNKE . . . . . *Repr. Pacific Northwest Section*
G. F. HUGHES . . . . . *Repr. Rocky Mountain Section*
D. R. PRINGLE . . . . . *Repr. Southeastern Section*
GEO. J. ROHAN . . . . . *Repr. Southwest Section*
W. B. HARMAN . . . . . *Repr. Virginia Section*
W. A. PEIRCE . . . . . *Repr. Wisconsin Section*

A. W. W. A. Final Approval Committee

JACOB SCHWARTZ, *Chairman* — C. J. ALFKE
L. D. BLUM — J. H. MURDOCH, JR.
W. W. DEBERARD, *ex-officio repr. Publication Committee*
MALCOLM PIRNIE, *ex-officio repr. Water Works Practice Committee*
P. S. WILSON, *ex-officio repr. A. W. W. A. Headquarters Staff*

This activity was organized in the fall of 1936, A. W. W. A. participation being under the auspices of the Finance and Accounting Division. The purpose is to prepare a complete Manual of Accounting for water works.

INTER-ASSOCIATION COMMITTEE ON CROSS CONNECTIONS

This committee is at present in process of organization, with representatives now appointed by the Conference of State Sanitary Engineers, National Association of Master Plumbers, American Public Health Association, New England Water Works Association, and American Water Works Association.

Representatives of A. W. W. A.:

E. SHERMAN CHASE — M. W. COWLES

The purpose of the committee is to co-ordinate the activities of the various professional groups with relation to cross connections and internal plumbing hazards.

A. S. M. E. JOINT COMMITTEE ON WATER HAMMER

Representatives of A. W. W. A.:

F. M. DAWSON L. H. KESSLER

This committee was organized in 1931 under the Hydraulic Division of the A. S. M. E. Mr. S. Logan Kerr is its general chairman. A symposium on water hammer was presented in 1933 and published as a separate publication by A. S. M. E. in 1934. It is planned to present a second symposium on the subject at the December, 1937 meeting of A. S. M. E. The committee has a very broad international representation.

A. W. W. A. REPRESENTATIVES ON COMMITTEES OF OTHER ORGANIZATIONS

GENERAL

PUBLIC HEALTH COMMITTEE OF THE NATIONAL ASSOCIATION OF MASTER PLUMBERS

Representative of A. W. W. A.:

ARTHUR E. GORMAN

This committee was formed subsequent to the outbreak of amoebic dysentery in Chicago in 1933, and is considering problems in connection with plumbing as viewed from the public health angle.

WROUGHT IRON AND WROUGHT STEEL PIPE, VALVES AND FITTINGS. STANDING COMMITTEE FOR SIMPLIFIED PRACTICE, NATIONAL BUREAU OF STANDARDS, UNITED STATES DEPARTMENT OF COMMERCE

Representative of A.W.W.A.:

SHEPPARD T. POWELL

CONSTRUCTION LEAGUE OF THE UNITED STATES, REPRESENTATIVES ON THE LEAGUE ASSEMBLY

WILLIAM W. HURLBUT
MALCOLM PIRNIE
ABEL WOLMAN
EUGENE F. DUGGER
PERCY S. WILSON

COMMITTEES UNDER THE PROCEDURE OF THE AMERICAN STANDARDS ASSOCIATION

A21—CAST IRON PIPE AND SPECIAL CASTINGS, SPECIFICATIONS FOR

American Gas Association

American Society for Testing Materials

American Water Works Association

New England Water Works Association

Representatives of A. W. W. A.:

Thomas H. Wiggin, *general chairman* Frank A. Barbour
William W. Brush William C. Hawley
Reeves J. Newsom

This committee has been engaged for some years in the preparation of a new standard specification for cast iron pipe and special castings to replace the present A. W. W. A. standard specification, and which will include centrifugal and other methods of manufacture as well as pit cast pipe. It will also include linings.

As noted above, T. H. Wiggin is the general chairman of the committee. The secretary is C. C. Simpson, Jr., (Am. Gas Assn.), 4 Irving Place, New York, N. Y.

A35—MANHOLE FRAMES AND COVERS

American Society of Civil Engineers

The Telephone Group (Bell System and U. S. Ind. Tel. Assn.)

Representative of A. W. W. A.:

Frank A. Marston

This committee is coöperating with the Division of Simplified Practice (U. S. Dept. of Commerce) in the standardization of design, material and dimensions of manhole frames and covers. The general chairman is L. B. Fish, (Bell System) 195 Broadway, New York, N. Y.

A40—PLUMBING EQUIPMENT, STANDARDIZATION OF

American Society of Mechanical Engineers

American Society of Sanitary Engineers

Representative of A. W. W. A.:

Walter S. L. Cleverdon

The general chairman of this committee is W. C. Groeniger, (A. S. S. E.) 3250 A. I. U. Citadel, Columbus, Ohio.

B2-1919—PIPE THREAD

American Gas Association

American Society of Mechanical Engineers

Representative of A. W. W. A.:

WILLIAM W. BRUSH

The general chairman of this committee is Alten S. Miller (A. G. A.), 80 Westcott Rd., Princeton, N. J.

B16—PIPE FLANGES AND FITTINGS

American Society of Mechanical Engineers

Heating, Piping and Air Conditioning Contractors National Association

Manufacturers Standardization of the Valve and Fittings Industry

Representatives of A. W. W. A.:

FRANK A. BARBOUR WILLIAM W. HURLBUT

The general chairman of this committee is Collins P. Bliss (A. S. M. E.), New York University, New York, N. Y.

B31—PRESSURE PIPING, CODE FOR

American Society of Mechanical Engineers

Representative of A. W. W. A.:

FRANK N. SPELLER

The general chairman of this committee is Edwin B. Ricketts, New York Edison Co., New York, N. Y.

B36—DIMENSIONS AND MATERIALS OF WROUGHT IRON AND WROUGHT STEEL PIPE AND TUBING, STANDARDIZATION OF

American Society of Mechanical Engineers

American Society for Testing Materials

Representative of A. W. W. A.:

FRANK N. SPELLER

The general chairman of this committee is Harold H. Morgan (A. S. T. M.), 2200 Insurance Exchange Bldg., Chicago, Ill.

C1—NATIONAL ELECTRICAL CODE

National Fire Protection Association

Representative of A. W. W. A. on Article 9, Sub-Committee on Grounding:

CHARLES F. MEYERHERM

The general chairman of this committee is A. R. Small, 109 Leonard St. New York, N. Y.

G8—ZINC COATING OF IRON AND STEEL, SPECIFICATIONS FOR

American Society for Testing Materials

Representatives of A. W. W. A.:

SHEPPARD T. POWELL

The general chairman of this committee is J. A. Capp (A. S. T. M.), General Electric Co., Schenectady, N. Y.

Z23—SIEVES FOR TESTING PURPOSES, SPECIFICATIONS FOR

American Society for Testing Materials

National Bureau of Standards (U. S. Dept. of Commerce)

Representative of A. W. W. A.:

GORDON M. FAIR

The general chairman of the committee is L. T. Work (A. S. T. M.), Columbia University, New York, N. Y.

Z32—STANDARDIZATION OF GRAPHICAL SYMBOLS FOR USE ON DRAWINGS

Representative of A. W. W. A.:

PERCY S. WILSON

COMMITTEES OF THE NATIONAL FIRE PROTECTION ASSOCIATION

ELECTRICAL CODE

See Committee C1 of the American Standards Association, above. These are identical committees.

FOREST

Representative of A. W. W. A.:

EDWARD E. MINOR

Fire protection and prevention for summer homes in forested areas.

HYDRANTS, VALVES AND PIPE FITTINGS

Representative of A. W. W. A.:

FRANK A. BARBOUR

PUBLIC WATER SUPPLIES FOR PRIVATE FIRE PROTECTION

Representative of A. W. W. A.:

J. WALTER ACKERMAN

Including the uniform marking of fire hydrants.

TANKS

Representative of A. W. W. A.:

LOUIS R. HOWSON

ABSTRACTS OF WATER WORKS LITERATURE

Key: Journal of the American Water Works Association, 29: 1, 10, January, 1937. The figure 29 refers to the volume, 1 to the number of the issue, and 10 to the page of the Journal.

LEGAL AND ADMINISTRATIVE PROBLEMS

Rights of Municipal Water Works to Appropriate Private Property. Leo T. Parker. W. Wks. Eng. 89: 765, 1936. Municipalities and water corporations are permitted to exercise the right of eminent domain, and thus acquire against even an unwilling property owner valuable rights in his land. It is the public interest and not the natural interest of the municipality, upon which domain is based. Courts have not permitted excess or speculative values to be placed on the land. When a property owner submits evidence that he was offered a certain price for the land, this is of no value, unless it came as a bona fide offer from someone capable of intelligent judgment. Where private property is taken by a municipality for water department purposes, the owner of such property may recover reasonable compensation for the property, or payment equal to the damages resulting from unlawful appropriations. A State law must distinctly and clearly give the municipality or water corporation the privilege of appropriating land. If the State law permits it is not necessary for the water corporation to have a franchise. Under no circumstances is the right of a city to acquire a water source and an easement over lands to lay its water mains and pipes an illegal and unlawful privilege. If the city offers a certain priee and later changes their mind, they are usually bound by their original agreement particularly as the municipality continues to benefit by the privilege. It is well established that where a nuisance is of such a permanent character that a single recovery can be had, including the whole damage, there can be but one recovery from the complaining property owner. However, the property owner may recover on a second suit based upon a substantially different wrong. Another important rule of the law is that only small compensation will be awarded to a property owner whose land beneath the surface is solely used for a pipe line.—*Lewis V. Carpenter.*

When can the Law of Water Easement be Enforced Leo T. Parker. 89: 825, 1936. A water easement is the right of a water corporation to use another's real property to secure, obtain or have a right of way to a water supply. A continuous easement is one which operates without the interference of man, such as a water course or drain. A right of way is not continuous, because in the use of it, there is involved the personal action of the owner. Easement and right of way is usually by contract but sometimes it is implied. A court principle says that "if one have twenty acres of land, and grant me one acre in the midst of it, hereby inclusive there is granted to me a way to it." Courts have frequently held that non-use of a water easement does not void the ease-

ment unless the non-use has extended over a period of years longer than specified by state law. Another important point of law is that once an easement attached to such property, although several portions are sold to a plurality of purchasers.—*Lewis V. Carpenter.*

Municipal Debt Liability. LEO T. PARKER. W. Wks. Eng. **89**: 1074, 1936. Courts of various states have not been in unison in their decisions as to municipal indebtedness to be paid from water works revenues. When a city purchases or constructs a new water works system and pledges the system and the income, with no other obligation of the city to pay the purchase or construction price, such contract does not create a "debt" in the strict sense of the word. The author cites twenty states wherein purchase of water works property does not affect the debt limit if the cost is to be paid from water revenues. The author further cites cases where the pledged water revenues did not meet the debt, the city is not liable for it. Various courts have held that an obligation of a city to fix and maintain water rates sufficient to pay the principal and interest of an indebtedness, with the stipulation that failure to maintain the rates shall never constitute an added indebtedness is not a debt of obligation which violates a constitutional debt limitation. It is invalid for a city to guarantee to purchase from itself, at a profit, power or water for its own use, unless the city has funds available for such purpose. Generally speaking, any obligation s illegal, which exceeds the constitutional debt limitation, if the entire water iystem is mortgaged to secure the payment of the debt.—*Lewis V. Carpenter.*

When may Municipal Officials make Valid Contracts. LEO T. PARKER. W. Wks. Eng. **89**: 1140, 1936. The courts have decided that the operation of a waterworks system is within the business powers of a city, and a contract will be governed by the same rules which control a private individual or a business corporation under like circumstances. Unless the law specifically prohibits, commissioners can contract for water business beyond their term of office. However, when public officials exercise strictly governmental powers, the officers of the city are trustees for the public and they make no grant or contract which will bind the municipality beyond their terms of office. Council are not permitted to enact unreasonable ordinances. Generally speaking, a contract of a city council to lease municipal property to private persons is valid, although it extends beyond the terms of the council executing it.—*Lewis V. Carpenter.*

Payment of Water Salaries When City Funds are Depleted. LEO T. PARKER. W. Wks. Eng. **89**: 893, 1936. It is important to know that the recent higher court decisions indicate that municipalities may pay their employees, although the state law and state constitutions do not provide that this money shall be derived from direct and indirect taxation. Ordinary regulations are inapplicable which limit municipal indebtedness when it is necessary for a municipality to violate a regulation of this nature in order to obtain money to pay salaries to its officials and employees. Bond issues to pay salaries can be issued even if the amount exceeds the legal limit. The law is well settled that the courts will not construe ordinary state statutes or city ordinances to in-

clude expenditures to be used exclusively for the benefit of individuals. As a case in point, author cites a state law, which provided for re-imbursing any official for expenses incurred in defending himself in any trial or proceeding that was instituted to remove him from office, or to convict him of crime in the performance of his duties, which was declared unconstitutional.—*Lewis V. Carpenter.*

When City is Liable for Injuries to Employees. LEO T. PARKER. W. Wks. Eng. 90: 22, 1937. Municipalities must exert reasonable care to prevent injuries to their employees, although there is no fixed standard to designate reasonable care. The obligations of a municipal corporation to use care to furnish its employees a safe place in which to work and safe tools and appliances with which to work are the same as that of a private employer, but the modern courts have upheld the older decisions that a state legislature may provide certain safeguards around municipal corporations to protect them. Working hours are defined and also what governmental functions are in case of damage suits. State compensation laws are designed to protect the workmen but any accidents compensated for must be during their regular working hours.—*Lewis V. Carpenter.*

WATER SUPPLY—GENERAL

Some Recent Developments in British Waterworks Practice. HAROLD J. F. GOURLEY. J. New Eng. W. W. Assoc. 50: 345–98, 1936. *Underground Water.* In England rights of riparian owners in respect to water flowing in visible surface streams or in defined channels do not apply to ground water. Public authorities are required to obtain approval of new wells which usually carries with it compensation for decreased yields of wells due to the pumping of the new public supply within a certain radius of protection extending usually 1 mi. in the chalk and 2 mi. for wells in the triassic sandstone. Same protection is not given public supplies and private concerns may put down wells near public wells of known ability to produce good yields. *Compensation Water.* Differing from this country, practice exists in England of providing "compensation water" to riparian owners whose interests may be affected by construction of public inpounding reservoirs. The amount of compensation water was arrived at by deducting $\frac{1}{5}$ or $\frac{1}{6}$ of the average rainfall to arrive at the average rainfall of the 3 consecutive driest yrs. and a further flat deduction made, usually 14 in., to cover loss by evaporation and absorption, the remainder representing the average run-off or maintainable yield during each of the 3 yrs. Quite often $\frac{1}{3}$ of this yield was fixed as compensation water leaving $\frac{2}{3}$ as the town supply. Because of application to cases where conditions were widely divergent, studies of problem were made by special committees. Discussion is given of a characteristic applied to streams to correct one of the objections to present method of detg. compensation water,—the fact that the present method does not allow sufficiently for the wide variations in the character of streams, i.e. flashy streams and those of steadier flow. This characteristic K, is the ratio $\frac{B}{A}$ in which (A) is the mean daily flow over the period of guaging (should not be less than 4 yrs.) and (B) the average daily flow on those days

when the river flow was equal to or less than the mean during the gauging period. K varies from 0.32 to 0.48 in 10 streams investigated, ideal stream would have K equal to 1. A "use factor" is also applied ranging from 0.35 for a river with few mills to 0.70 for a fully industrialized river. Examples given of application to River Brenig in North Wales and River Thames. *Regional Water Supplies.* Studies were started 1935 leading to development of supplies by regional areas rather than by individual communities. *The Drought 1933–35.* Conditions during drought of 1887–89 have been those used for water supply design but it is recognized drought of 1933–35 will modify these factors. Committee of Inst. of Water Engs. has not completed studies but one factor indicated is that run-off from catchments and percolation which replenished ground water is not so much function of rain fall of a period of yrs. as of the incidence of that rainfall. Not only general rain-fall deficiency in the 1933–35 led to difficulties, but also the serious deficiency in the rain-fall of the winter months when normally both reservoir and underground storage is replenished. Records of percolation guage in a natural section of chalk with soil and grass cover gave following average results for nearly 40 yr. period; rainfall for 6 winter months 14.32 in., percolation 9.56 in.; corresponding figures for summer months being 12.47 and 1.99 respectively. *Floods.* The English 1930 Reservoir Act provides for inspection of reservoirs by qualified engineers whose duties include consideration of adequacy of spillway. Reservoir failures throughout world have often been caused by inadequate provision for discharge of flood waters. Investigation by an Engineer's Comm. followed these findings. Actual records of floods gave curves of "normal max. floods" which would be liable to occur once every 50 to 60 yrs. Comparison with flood figures of Mar. 1936 in New England indicated good agreement with these curves in cases of similar watershed areas. Some additional details of Comm.'s recommendations are also given. *Circular Spillways.* An extensive discussion is given of circular spillways which of recent yrs. have come to be more frequently used. In many situations considerable economy in construction results from its use since the bellmouth can discharge into a shaft which, in turn, discharges into the culvert or tunnel which carried the river past the site during construction of the dam, avoiding the cost of an entirely separate weir and overflow channel. A table is given showing available details of the spillways of this type in the British Empire. Considerable detail with curves of model expts. with this type of spillway is given. *Dam Construction.* Important details are given of the design and construction of the Shing Mun Dam at Hong Kong and the Silent Valley Reservoir of the Belfast Water Supply. The Shing Mun dam is 265 ft. above river bed and 750 ft. long and is believed to be highest structure of its kind in British Empire. Discussion. ROBERT E. HORTON. It is pointed out that well fields may not be circular but somewhat in shape of narrow rectangle; with, as a rule, the direction of flow of the groundwater parallel to longer axis of rectangle. Electrical methods may now be used to plot the lines of flow of a well field, and detn. of boundaries may be of decided economic value. H. believes compensation in kind, if carried out on an equitable basis with due consideration for all uses to which the stream would ordinarily be put, affords a better economic solution of diversion problems than absolute taking of water and payment therefore. The use of the

characteristic K suggested by Gourley for detng. variability of streams is favored until methods become more generally available for detng. the ratio of the groundwater flow to the total run-off, or in some cases, the ratio of the outflow derived from storage in all forms, to the total run-off, which would appear to be the best possible characteristic. In providing factor of safety in spillway design, H. believes in a majority of instances, reservoirs should be constructed with spillway capacity adequate to take care of max. possible flood on the drainage basin. Max. possible flood on a given basin area will be produced by the highest rain intensity which occurs at a time when the infiltration capacity of the soil is at a min. and which lasts long enough to bring surface run-off rate up to equality with difference between rain intensity and infiltration capacity. In analysis of flood magnitudes "average flood" is preferred to average annual flood because of lack of flood records of 25–50 yrs. duration and providing of 2–3 times as many data. CALEB MILLS SAVILLE. Discussion of original paper particularly with reference to Hartford supplies. Comparisons of characteristic K show streams in British Isles and Southern New England to be much alike. In "use" coefficients problem of water quality is brought out. MALCOLM PIRNIE. Data are given of studies of underground water in 3500 sq. mi. on Florida Peninsula. Average intake from average rainfall amounts to 11.96 in. or 23% of a 52 in. rainfall, comparing favorably with 11.55 in. recorded in England with percolation guage. In Florida, a single rain of less than 0.30 in. contributes practically nothing to run-off and ground water replenishment, rain of 0.60 in. is probably required to be effective in water production. Under this assumption half of rains in 12 months of drought were ineffective.—*Martin E. Flentje.*

Planned Utilization of Water Resources. A. E. MORGAN. Civ. Eng., 7, 255, 1937. Before considering the broader problem of an adequate system of planned utilization of water resources, it will be helpful to review the more or less spontaneous growth of water developments in the United States, and the results that have been achieved. River-control practice has suffered from two types of extremists. One class of engineers has maintained that control must be achieved by levees supplemented by channel dredging. The opposing group proposes a large number of small reservoirs on the headwaters as an adequate means for control on the lower river. The conflict between these two uncritical dogmas has been a great handicap to effective and economical flood control. The time is approaching when an assembling and a thorough analysis of facts may determine policies in this and other phases of the planned utilization of water resources. In arid regions agriculture and community life depend on large-scale irrigation. This demands that the United States shall become a true nation, and not merely a group of independent states bound together by a treaty called the constitution.

As the country has become more thickly settled and water consumption for both domestic and industrial uses has increased, it has become recognized that many problems of water supply are no longer local and isolated, but are of state, regional, and national importance. In relatively few cases have there been any attempts to combine the various uses of water into a unified whole for the development of an entire river system. Another important problem is

the prevention of stream pollution. If our water resources are to be utilized in a planned and integrated manner, we must discover their possibilities and exercise guidance and control in their development. Water is a public resource. It pays no attention to property lines and it changes its location. All these factors indicate the need for public ownership and administration, which should be non-partisan, non-political, business like, and technically efficient. One of the first essentials for economic planning and execution of multi-purpose water-control projects is the assembling of underlying data and the making of basic surveys. In the planning of specific structures the value of unified development is also apparent. In the actual construction of dams the value of a unified program and orderly sequence of development is again evident. As the United States has developed from a nation of pioneers to a highly organized industrial people, the use of water has changed gradually from unregulated exploitation by the first claimant to the beginnings of orderly planning and systematic control.—*H. E. Babbitt.*

Record Breaking Consumptions. ANON. W. Wks. Eng. **89**: 1234, 1936. A survey made on the high demands for short periods during the severe drought and high summer temperatures of 1936 gives some good data for designing of water systems. In the cities of from 10,000 to 20,000 population, the maximum consumption for one day is 1.9 times the average recorded for June 1935; for three days the consumption averaged 1.82 times the June figure, and one the one-hour demand basis this rate rose to 3.25.—*Lewis V. Carpenter.*

Determination Of and Means For Reduction of Water Waste. J. P. HANLEY ET AL. Am. Rway. Eng. Assn. **38**: Bulletin 389, 107, (1936). Annual cost for operation and maintenance of water supply on American Railroads will exceed $30,000,000. Common sources of water waste are listed. Constant vigilance is required on the part of employees and supervisory forces to save water and reduce expense.—*R. C. Basdwell.*

Surface Supply to Replace Scant Ground Water Resource. F. M. VEATCH, W. Wks. Eng. **89**: 758, 1936. Wellington, Kan. has well supply with hardness of 12 grains which at times has proved inadequate. Now has developed a surface supply with an average of 7 grains hardness. Filtration plant is typical rapid sand plant with aeration, mechanical mixing, coagulation, and filters. Well supply will be retained as a reserve supply.—*Lewis V. Carpenter.*

Water Works of Fort Smith, Ark. C. F. BYRNS. W. Wks. Eng. **89**: 1068, 1936. Fort Smith went 25 miles to Clear Creek where an 80-foot high earth dam was constructed to impound a water supply. The dam is 2,050 feet long of which 1800 feet is earth and 250 feet spillway cut out of solid rock in the side of the mountain at the west end of the dam. The water supply is filtered at the reservoir site. The pipe line was welded steel and was stripped in 40-foot sections and is lined with bitumastic enamel. The joints were made with Dresser couplings.—*Lewis V. Carpenter.*

Softened Water Quadruples Demand. FRANK BEARD. W. Wks. Eng. **89**: 886, 1936. The City of Kahoka, Mo. tapped an underground lake for a munici-

pal water supply. A single 20 inch well was drilled and cased 10″. The outside was gravel packed. The addition of lime and sodium aluminate in their treatment plant reduced the solids from 44 grains per gallon of total soluble mineral solids of which 23 were incrusting solids to a hardness content of 3 to 4 grains. The consumption jumped from 10,000 gallons daily to 40,000 gallons. The town has a population of 1600.—*Lewis V. Carpenter.*

Little Rock, Arkansas New Water Supply. MARION L. CRIST. Sw. W. Wks. J., 18: 14 (1937). Brief description of the 14 mil. gal. lake, 2800 ft. earthen dam and the 39 in. reinforced concrete pipe flow line.—*O. M. Smith.*

WATER QUALITY

The Sterilisation of Drinking Water with Minimal Doses of Chlorine. T. N. S. RAGHAVACHARI AND P. V. SEETHARAMA IYER. Water and Water Eng., 39, 115 (1937). Report is made on experimental work with chlorination carried out to ascertain if waters could be sterilized by doses of chlorine smaller than the optimum dose which satisfies the demands made on the chlorine by the oxidisable organic and inorganic matter and maintains in addition a residual chlorine content of 0.10 to 0.20 p.p.m. after a 20 minute contact period. Chlorine dosage tests on 32 samples of water from widely varied sources showed 5 samples were rendered free of lactose fermenting bacteria following treatment with chlorine dosage of 0.05 p.p.m., 0.10 p.p.m. was effective in 11 cases, 0.20 p.p.m. in 4, and 0.30 p.p.m. of chlorine was required for sterilisation in 10 others. In these waters the optimum chlorine dose varied from 0.50 to 1.50 p.p.m. No relationship was found between optimum and effective doses; one water with chlorine demand of 1.5 p.p.m. and showing lactose fermenters in 0.01 cc. was sterilized with a 0.30 p.p.m. chlorine dose, another water requiring 1.10 p.p.m. chlorine and having lactose fermenters in 10 cc. was effectively sterilized by a 0.05 p.p.m. dose. Following publication of articles bearing on this problem (Nachtigall and Ali, Jour. Amer. W. W. Assoc. 4; 430-31 (1934) and Ibid. P. Bunau-Varilla, 26, 10: 1536–44 (1934)) additional experimental work was begun. These articles discussed process known as "Verdunisation" for which it is claimed sterilization can be accomplished by chlorine doses of 0.10 p.p.m. for clear waters and 0.20 p.p.m. for all waters, provided vigorous agitation accompanies the addition of the chlorine. Process is reported as being in successful use in Paris, Lyons, Brussels, Geneva and other cities. The Bunau-Varilla method was tried out on a second set of 60 samples of representative drinking water supplies scattered over Madras Presidency, no conscious selection as to source being made. Each sample was divided into 5 portions; portion A receiving optimum ascertained chlorine dose, stirred with glass rod 12 times and allowed to stand 20 minutes; B and C each received a minimal dose of 0.10 or 20 p.p.m. chlorine depending upon whether sample was clear or turbid, B was stirred 12 times and C vigorously shaken for 10 min. and set aside for 10 min., B being allowed to stand 20 min.; D received no chlorine but was shaken in same manner as C; portion E served as control and represented water at source. Results show toxic action of chlorine even in minimal dosages to be permanent. Lactose fermenters were found absent in 60 cc. quantities from all the clear water samples; in all of the A, B and C portions. The optimum chlorine dosages varied from 0.40 p.p.m. to

1.3 p.p.m. In cases of slightly or highly turbid samples only 60% success was obtained with 0.20 p.p.m. dose. D portions subjected to shaking only were bacteriologically much worse than controls E, possibly due to dispersion of clumps of bacteria present in original water. In discussion of results authors state it would appear that the bacterial sterilization of drinking water, particularly of the clear water from wells and filter plants, can be effected by using 0.10 p.p.m. of chlorine empirically. Authors do not feel vigorous agitation is most important factor controlling success or failure of minimal dose, although question is raised whether simple stirring in A and B portions above could be classed as agitation sufficiently violent to set up verdunisation effect. Conclusion is reached that the results of the application of minimal doses of chlorine to 100 samples of water from different sources scattered over Madras Presidency, show that clear water from wells, galleries, and filter plants can be sterilized by amounts of chlorine, which, in many cases, are from a fifth to a tenth that of the optimum ascertained doses. Attendant advantages are cited.—*Martin E. Flentje.*

Resistance of various strains of E. Typhi and Coli Aerogenes to Chlorine and Chloramine. L. S. Heathman, G. O. Pierce, P. Kabler. Pub. Health Rep. 51, 1367, 1937. Brief resume of literature is cited to show development of bacterial examination of water using B. Coli as indicator organism for contamination. The research reported on was carried out because of the scarcity of comparative data on the resistance of freshly isolated and older strains of B. typhosus and coli—aerogenes to the modern disinfectants used in water treatment and using city water as the diluent. Chlorine disinfection was compared with chloramine treatments. Tap water from distribution system was used for chloramine tests and combined filter effluents after prechlorination for chlorine tests. Water contained negligible quantity of nitrites, iron or magnesium, pH varying from 6.4 to 7.4 for chloramine test water and 7.0 to 7.9 for chlorine tests. Tap water mixed to get desired residual due to chloramines, chlorine tests treated with chlorine water. Sufficient volume of 24 hr. broth cultures of either E. typhosa or a member of coli-aerogenes group added to test water to give conc. of 80 to 850 bacteria per cc, and in later tests between 150 and 350 per cc. At end of 5, 15, 30 min. and 1, 1½, 2 and 18 hours 2 1-cc. portions of water under test were removed and plated in brom-cresol purple lactose agar, calories then being counted after 48 hrs. at 37 degrees C. In later experiments killing power of chloramines was determined for a strain of E. typhosa and for a member of coli-aerogenes group at both room and ice water temperature, platings being made as before but at 30 minute intervals up to 2½ hrs. exposure and then after 18 hrs. The majority of the bacterial cultures were recently isolated strains but a few old lab. strains grown for years on artificial media were also used to inoculate water. In preliminary experiments it was found longer time was required to kill recently isolated strains of E. typhosa with chlorine than to kill an old lab. strain (Rawlings). Recently isolated strains were also, in general, found more resistant to chloramines, these facts indicating prolonged growth as artificial media materially reduces resistance to disinfecting action. Considerable variation in killing power of chloramines was found from day to day even with

same residual and temperature range. In majority of instances, 29 out of 34, time required to kill recently isolated strains of E. typhosa was equal to or in excess of that required to kill members of coli-aerogenes group, this also being true in 18 out of 34 cases at low temperature. Some strains of E. typhosa may therefore, under certain conditions, exhibit as great or greater resistance to chloramines than coli-aerogenes. It was clearly demonstrated at lower temperatures longer time is required for disinfection with chloramines and in some instances with chlorine. Chlorine alone in the low initial residual ranges exhibits a killing action very similar to chloramines, requiring an hour or more to kill at room temperature which time is considerably lengthened at low temperatures. At higher residual values, 0.18 p.p.m. and over, approximately ½ of waters studied resembled chloramine tests in that time required to kill coli-aerogenes was equal to or in excess of time to kill strains of E. typhosa. Approximately ½ of tests in higher residual range, 0.18 p.p.m. and more, killed all bacteria before first tests, i.e. within ½ hour exposure to disinfectant, at both room and low temperature. Conclusions reached were to the effect that disinfecting action of chlorine is variable within limits; in some instances low temperature requires longer killing period for both chlorine and chloramines; considerable variation exists in resistance to disinfection in freshly isolated E. typhosa and coli-aerogenes strains; old laboratory strains exhibit less resistance to disinfection than fresh strains; possibility exists of E. typhosa existing in water as long as or longer than coli-aerogenes; results indicate desirability of reconsidering significance of coli-aerogenes group as bacteriological index of the safety of a chlorinated water.—*Martin E. Flentje.*

Metropolitan Water Board (London) 30th Chemical and Bacteriological Report for Year Ending December 31st, 1936. 101 pp. P. S. King & Son, Great Smith Street, Westminster, London. The previous report was prepared during a serious drought. This one was prepared during equally serious flood which, though it was destructive, replenished underground natural reservoirs. Samples are taken on each working day, 30,101 being examined in 1935. Raw water is especially variable. B. Coli in stored sources may be negative in 1 ml. and be positive in river water during flood in as little as 0.000001 ml. It is practice to restrict withdrawal of raw water from the Thames when the clarity is reduced to 2 ft. or B. Coli presumptive positives appear in 0.05 ml. Samples from the filters are taken during the time of highest rate of production. The colony count is usually 5 per ml. and under and a unit is reported if it exceeds 10 per ml. The multiple tube method of examination for B. Coli is used only on unknown samples. Of the untreated filtered water samples, 70% are 1st class which contain no B. Coli in 100 ml. If B. Coli is found in 10 ml. the filter is reported to the Works Engineer and if in 1 ml. a special investigation is made and the unit taken out of service. The appearance of B. Coli in 100 ml. of finished water is the cause of prompt investigation. The same rigid standard applied to treated water is also applied to well water going directly into the supply. The use of the faecal streptococcus test has been continued. Inferior peptone caused anomalous results without affecting the B. Coli results. From polluted wells, etc., isolation may be made on Conradi-Drigalski plates. Mac Conkey's medium is better for rivers and good

wells. They may be present in 250 ml. of filtered water but the method is involved, requiring centrifugalisation before planting on Conradi medium. The Clostridium Welchii test is best made by heating the sample to 80°C and incubation in litmus milk. It is of doubtful value as compared to the more delicate B. Coli test. The Viability of Coliform organisms was investigated in Thames river water, untreated and sterilized with ozone, chlorine and by boiling. The presence of saprophytic survivors is believed to interfere with the multiplication of coliform organisms and hasten their disappearance in stored samples. The storage of water is necessary to insure continuity of supply. Another advantage lies in the reduction of significant bacteria by replacing a fluviatile with a lacustrial environment, promotes algal multiplication, especially in the midsummer. Variation of fauna and flora in adjacent reservoirs is attributed to differences in shape, depth, position of inlet and outlet and time of retention. In reservoirs having multiple outlets, the chemical and biological examination of definite depth samples indicates the most suitable level from which to draw. The "resistance to filtration" (determined by the time required to pass a given volume of water through a special linen filter, described in the 18th Annual Report) has been found to correlate well with algae density in stored waters where the silt content is negligible.

The concentration of some inorganic salts is thought to influence algae density. It has been noted that oxidized nitrogen and hardness are lower with increase in plankton. It is possible that concentrations of phosphates, nitrogen and silica may fall so as to limit growth. During periods of low silica content zeolite softeners suffer damage entailing a considerable loss. The period of greatest damage coincided with that in which the greatest number of diatoms were found. For this reason phosphate and silica determinations have been made routine.

Cuprichloramine in concentrations above 3.0 p.p.m. are effective against adult forms but the zygote stage is resistant. Some motile forms are able to pass sand filters as may be demonstrated by passing the filtered water through cotton plugs which may be stained by them. The mucoid layer surrounding some diatoms which live in the filters is thought to be effective in retaining bacteria. During periods of low algae production (in cold weather, for instance) low bacterial efficiency of the filters is observed.

The Chinese Mitten Crab (so named on account of curious hair-like growth on the pincers) has become wide spread in German and Dutch rivers, brought, supposedly, in ballast water. Only one specimen has been taken in English waters. Eggs are laid in salt water and the young migrate into fresh water, remaining until sexually mature. Their tunnels damage stream banks and the flat worm causing human Paragonimiasis (endemic in the far east) passes part of its life cycle in them. The fact that crabs are not consumed raw reduces the danger of the disease becoming important in England.

The chemical laboratory is concerned with special problems as well as routine examinations. Frequently leakage water may be identified as coming from the supply or otherwise. Zinc is found in water delivered by new pipes and causes turbidity and irridescent film. Samples of zinc coated iron plate were tested in water and solutions of tribasic sodium phosphate, which is used as a softener in cold cisterns. The phosphate increases the action on the

zinc. Methods of testing for zinc, phosphate and silica are given. In only one well, always mixed with other water before delivery, does fluorine occur in physiologically significant concentrations. Except for the treatment of Rye Common well, which began in 1910, the first chlorination of river water was applied to raw Thames water in the Staines Aqueduct in 1916. In 1921 the first full scale experiments were made on a filtered water. The close of 1935 marks the chloramination of all river derived water. Prechlorination is applied to only two supplies. Chlorine dosages vary from 0.15 p.p.m. to 0.25 p.p.m., which may be increased in cold weather. Prefiltration waters are examined weekly for resistance to filtration and quantitative photo-micrographs are made fortnightly. The pictorial record is complete for 20 years and contains more than 2000 pictures. Prefiltration is described in the 13th Research, and the 21st Annual Reports. Physical improvement is obtained which has increased final filter rates. Chlorination is an essential adjunct to the system of double filtration since the prefilters retain plankton responsible for bacterial retention in the final filters. Chlorination equipment is maintained at all stations ready for immediate use. There are 178 slow and secondary filters with a combined area of 175 acres. Some have functioned for almost a century. Storage and filtration are considered to be the main safeguards irrespective of chemical treatment. All of the water supplied to the consumer yields 95.7% of first class samples as compared with 72% after filtration. Five years after the paratyphoid outbreak at Epping, and with a percolating filter sewage plant in service, the paratyphoid B. concentration is about 3 per ml. in the effluent, which is a material reduction over previous years. It is taken as evidence of the inability of modern sewage treatment works to eliminate pathogens.

All complaints are investigated. In 1935 there were 238 as compared with 254 in 1934. This is 0.0031% of the population served. The chief cause was taste of which there were 91, 34 being accepted as justified. Most of them come from low circulation districts in warm weather. There were 20 complaints of insects (Asellus and Gammarus) which may penetrate filters (as do certain algae) or come from wells. The opinion is given that the sewage entering the Thames (27 m.g.d.—minimum river flow 140 m.g.d.) should be treated at numerous smaller plants rather than in one large one with discharge below all domestic water intakes. The effect of storm water from the present "trim townships" is minimized. Separate systems of collection are advocated. Storage has been discussed in the past from a hygienic standpoint. Following the drought emphasis is placed also on *quantity* in storage. Plans are made to increase the present net storage of 18000 m.g. to 30000 m.g. Water for storage is to be taken from the streams, in so far as possible, following scouring floods. (Thus they are not available for flood control). The water of the Thames and Lee are shown to be of very much better bacteriological quality in drought than flood stage. The maximum recorded per capita per day use of water is 44.5 gal. which was reduced by propaganda to less than 35 gal. during the drought. The minimum permissable flow of 170 m.g.d. below the intakes was reduced in the extremity, to 50 m.g.d. which saved the situation. In wells and springs, atypical B. Coli forms are indicative of approaching dangerous pollution rather than distant pollution. In streams. and through storage and

treatment works, typicals disappear more rapidly than atypicals. Covered beds, where algae do not grow, show poorer efficiency. There is no evidence to show that coliform bacteria multiply in filters. Colony counts are made on agar at 37°C and incubated for 24 hrs. 10 ml. of filtered water are used mixed with 40 ml. of 2½% agar. Samples for B. Coli examination are added to concentrated media to give a resultant normal strength. After the sample is added to the media the tube is held in a water bath at 40°–42°C for 2 hrs. and incubated at 42° for 20–24 hrs. Subsequent incubations are at 37°. Filtered waters, in 10 ml. amounts, are incubated for 18 hrs. for indol production. Positives are planted on neutralized lactose bile-salt and neutral red saccharose bile-salt agars and colonies from each planted in peptone water, lactose gelatine (litmus tinted) and saccharose gelatine (neutral red tinted.) Confirmation and classification are made on the basis of growth in these media. Atypical forms increase in spring and summer, especially in filtered water. Investigation of the types of bacteria in the supply is carried on to increase knowledge of the meaning of the various tests.—*C. K. Calvert.*

The Spread of Tularemia Through Water, as a New Factor in its Epidemiology. S. P. Karpoff and N. I. Antonoff. J. Bact. 32: 3, 243, 1936. The authors conclude that, "a new mode of spread of tularemia, its spread by water, was proved experimentally and bacteriologically. The quantity of microörganisms in the infected water courses may sometimes be so considerable, that their isolation does not meet with great difficulties. 100 percent of the guinea pigs infected with the water died and their organs showed characteristic pathological-anatomical changes. From the organs of all these guinea pigs by water we obtained cultures of *B. tularense.* The cultures isolated from water did not differ in regard to virulence from those that were isolated from the suppurated lymph glands of patients. When these cultures were tested on guinea pigs, death followed in 100 percent of cases and the organs showed changes characteristic of tularemic infection."—*Ralph E. Noble.*

The Purification of Water for Drinking. A. H. Waddington. Chem. and Ind., 55: 65, 1936. Traces history of development of water purification, slow sand filtration, introduction from America of rapid filtration, pre-settlement, chemical treatment, softening, chlorination and water borne diseases. Two most important factors in coagulation are pH value and nature of colloidal matter to be removed. Discusses treatment plant to convert turbid, colored, bacteriologically impure river water into clear, colorless, non-corrosive and sterile drinking water. Chemical tests to have lost much significance in judging suitability of water, since pure waters may derive ammonia, nitrates, nitrites, etc. from geological sources or from chemical treatment or even from sewage. Appearance, palatability, pH value and bacterial purity are now most important data.—*W. G. Carey.*

Influence of Water Pipes on Iodine Content of Water. W. P. M. Matla. Chemisch Weekblad, 33: 570, 1936. Iodine content reduced by passing through copper or asphalted iron pipes, but no reduction occurs in lead, tinned copper or galvanized pipes.—*W. G. Carey.*

Drinking Softened Water. R. C. BARDWELL AND E. L. E. ZAHM. Railway Eng. and Maint. 33. No. 2, 112 (1937). The effect on fitness for drinking of the softening of water for locomotive boiler use depends upon the type of treatment used. Pathogenic bacteria are eliminated in the properly operated lime-soda plant and the slight causticity remaining can be removed by alum or copperas treatment and filtration, if considered desirable. Where the zeolite method is used or the wayside tank system with only partial chemical treatment, supplemental treatment with chlorine or such handling as required by the individual case should be applied.—*R. C. Bardwell.*

Prevention of Goiter in Michigan and Ohio. O. P. KIMBALL, M.D. Jour. Amer. Med. Assoc. **108**: 860, 1937. "The Michigan State Dept. of Health made a survey of representative sections of the State in 1923 to determine (1) the incidence of goiter among school children, and (2) the amount of iodine in the water supply of each section. Naturally the amount of iodine in the water supply is the best index to the food iodine found in that section." "The results of the first survey showed beyond a doubt that there is a correlation between a scarcity of food iodine and a high incidence of simple goiter." "From this study it is apparent that the incidence of goiter in any county is inversely proportional to the iodine content of the water supply." A state-wide campaign was undertaken to emphasize the fundamental causes of endemic goiter, the principles of its prevention, and to promote the use of iodized salt. In 1928 the Dept. made a study which included an investigation of the efficiency of the general use of iodized salt as a method of prevention. Detailed data of the two surveys are given. "This survey shows conclusively that the general use of iodized salt is an efficient and safe method of goiter prophylaxis." —*J. H. O'Neill.*

The Investigation of Goiter and Cretinism in Bavaria. ANON. Jour. Amer. Med. Assoc. **108**: 986, 1937. This investigation was initiated ten years ago by the German Institute of Psychiatric Research of Munich. The districts studied were primarily those in which there was a high incidence of goiter and cretinism. A progressive increase in incidence was found from the southern and western section of the region toward the northern and eastern sections. "This fact, together with consideration of such geological phenomena as weathering of the soil, led to the setting up of a so-called soil decomposition theory of endemic goiter, cretinism and feeblemindedness. This theory is based almost entirely on the physical factors underlying the production of a soil in which the noxa of goiter is present. Systematic computations have revealed a clear interrelation between the radioactivity of a soil and of the ground-air and the severity of endemic goiter. It was furthermore disclosed that besides the quantitative difference in the content of ground-air emanations there is also a qualitative difference: in severely affected goiter zones a greater quantity of radon is found, in goiter free regions more thoron is found." "Examinations of soil specimens spoke against the theory of iodine deficiency." Feeding experiments were conducted with rats. Goiter appeared in from three to five months in animals, kept within an exceptionally well defined goiter zone, but which received "an abundantly varied regimen es-

pecially such as iodine and vitamins"; all food products being imported from goiter-free areas. "The rats accordingly received nothing indigenous to the place of experiment except the air they breathed, nor had they any contact with the ground."—*J. H. O'Neill.*

Chronic Endemic Dental Fluorosis. H. Trendley Dean, D.D.S. Jour. Amer. Med. Assoc., 107: 16, 1269, 1936. "The endemic hypoplasia of the permanent teeth known as chronic endemic dental fluorosis, or mottled enamel, is a water borne disease associated with the ingestion of toxic amounts of fluorides in the water used for cooking and drinking during the period of calcification of the affected teeth." There is a definite quantitative relation between the fluoride concentration and the clinical effect. From the continuous use of water containing about 1 p.p.m., it is probable that the very mildest forms of mottled enamel may develop in about 10 percent of the group. In waters containing 1.7 or 1.8 p.p.m., the incidence may be expected to rise to 40 percent or 50 percent, although the percentage distribution would be largely of the "very mild" and "mild" types. At 2.5 p.p.m. an incidence of 75 to 80 percent might be expected. The article, with discussion, reviews present knowledge of the subject and has an excellent list of references.—*John H. O'Neill.*

LABORATORY METHODS—BACTERIOLOGICAL

A Critical Study of Some of the Growth-Promoting and Growth-Inhibiting Substances Present in Brilliant-Green Bile Medium. C. N. Stark and L. R. Curtis. Jour. Bact. 32: 375, 1936. "The use of 0.00133% brilliant green in 1% peptone and 1% lactose completely inhibited growth of all members of the *Escherichia-Aerobacter* group, tested. The addition of 2% dried oxgall to 1% peptone and 1% lactose definitely accelerated growth of the *Escherichia* (species) studied. This amount of dried oxgall retarded slightly the growth of the *Aerobacter aerogenes* (cultures) used. The toxicity of 0.00133% brilliant green is materially reduced by addition of 2% dried oxgall to 1% peptone and 1% lactose. 2% dried oxgall added to 1% peptone and 1% lactose supported growth of certain sporulating aerobic and anaerobic bacteria which may be responsible for false tests. The addition of 0.00133% brilliant green to 1% peptone, 1% lactose and 2% dried oxgall, completely inhibited growth of all false-test sporulating bacteria tested. The addition of 0.00133% brilliant green to 1% peptone and 1% lactose or 1% peptone, 1% lactose and 2% dried oxgall failed to inhibit growth of certain bacterial cultures which could be responsible for false tests by means of 'synergism.' That additional protein material definitely reduces toxic action of brilliant green, in the brilliant-green bile medium, was demonstrated by the addition of 1-cc. amounts of sterile milk to 14 cc. of the medium. This additional amount of protein material resulted in growth of some of the sporulating, false-test organisms, and in growth of an even larger number of cultures which may be responsible for false tests by means of 'synergism.' These findings have special significance in the use of brilliant-green bile medium to test milk for the presence of members of the *Escherichia-Aerobacter* group. These studies, it is believed, further

emphasize the dangers involved in the use in culture media of any inhibitory substance, the toxicity of which is influenced by the amount of protein and the reaction of the medium." (Abstractor's Note: No evidence or data included in this work to support the last six words of this conclusion).—*Ralph E. Noble.*

Increased Growth and Gas Production by Escherichia-Aerobacter Organisms in Brilliant-Green Bile Medium Containing Sodium Formate. C. N. STARK AND L. R. CURTIS. Jour. Bact. 32: 385, 1936. "It has been shown that brilliant-green bile medium as now used, does not inhibit growth of all bacteria which may be responsible for false tests in the analysis of water and milk. Addition of 0.5% sodium formate to brilliant-green bile tended to increase the rate of growth of *Escherichia-Aerobacter* organisms and resulted in the presence of a larger number of organisms. 0.5% sodium formate added to brilliant-green bile caused an earlier production of gas and formation of two to three times as much gas. Addition of 0.5% sodium formate did not materially influence the growth of organisms which may be responsible for false tests."—*Ralph E. Noble.*

The Action of Hexamethylenetetramine on Members of the Colon and Aerogenes Groups. CHARLES F. POE AND J. HOWARD WILLIAMSON. J. Bact. 32: 281, 1936. "The members of the *Aerobacter* group grow in liquid media containing a greater concentration of urotropin than do members of the *Escherichia* group. The media cannot be used to differentiate the two groups as claimed by Wilson. Urotropin media become more toxic with passage of time and at higher temperature because of the production of formaldehyde. Solid media containing urotropin also fail to differentiate between the *Escherichia* and *Aerobacter* groups of bacteria."—*Ralph E. Noble.*

The Influence of the Composition of the Medium on the Metabolism of Some Slow-Lactose-Fermenting Bacteria of Intestinal Origin. A. D. HERSHEY AND J. BRONFENBRENNER. Jour. Bact. 32: 519, 1936. "The metabolism of a slow-lactose-fermenting strain of the *Escherichia coli* type, and of its rapidly fermenting variant, in lactose-containing synthetic media, have been studied. Figures are given showing the development of cultures and accompanying metabolic changes as they occur in these media in relation to lactose concentration, and to the presence of an additional source of carbon. Variation within the culture does not play any part in the early course of fermentation by these bacteria. Multiplication rate, and velocity of lactose fermentation, are markedly influenced by concentration of lactose in the medium. Effect on the rate of fermentation is direct, as well as dependent on changes in rate of growth. Rate of fermentation varies with bacterial population of the culture, while rate of respiration is largely independent of it. This divergence between rates of fermentation and respiration is discussed without reference to 'phases of growth.' Presence of sodium succinate as an accessory source of carbon does not appear to influence early lactose fermentation, except through its buffer-effect on the pH of the culture. Succinic acid is removed from the medium more rapidly as the ratio of the concentration of succinic acid to that of lactose is increased."—*Ralph E. Noble.*

LABORATORY METHODS—CHEMICAL

Methods for Analysis of Chemicals Used in Water Treatment. R. M. Stimmel et al. Am. Rway Eng. Assn. 38. Bulletin 389, 102 (1936). Standard method is recommended for Sulphate of Alumina. Rapid method for testing Zeolite regenerate salt recommends testing for Cl with standard Ag NO_3. Tentative precision method suggests precipitation with conc. HCl and test of filtrate with Magnesium Uranyl Acetate Solution.—*R. C. Bardwell.*

A Photoelectric Method for the Determination of Phosphorus. C. W. Eddy and Floyd DeEds. Ind. Eng. Chem., Anal. Ed., 9, 1, 12–4 (1937). Photoelectric colorimeter is applied to accurate determination of 0.001 to 0.01 mg. of phosphorus in 5 cc. of solution, using Kuttner and Lichtenstein modification of phosphomolybdate method.—*Selma Gottlieb.*

Photometric Determination of Silica in Sea Water. Rex J. Robinson and Herbert J. Spoor. Ind. Eng. Chem., Anal. Ed., 8, 6, 455–7 (1936). From photometric study of determination of silicate in marine waters by silicomolybdate method, it is concluded that (1) buffered potassium chromate solutions are preferable to picric acid solutions as permanent standards; (2) maximum silicomolybdate color develops within three minutes and is constant for at least two hours; (3) temperature variation of 10 to 15°C. does not influence color development; (4) maximum color is developed between pH 1.5 and 2.3; (5) in marine waters either hydrochloric or sulfuric acid may be used for acidification; (6) results obtained on sea water should be multiplied by 1.16 if comparison is made with standards valid for fresh water.—*Selma Gottlieb.*

Determination of Semi-Microquantities of Phosphates. N. Howell Furman and Harold M. State. Ind. Eng. Chem., Anal. Ed., 8, 6, 420–3 (1936). 0.65 to *circa* 16 mg. of phosphorus were satisfactorily determined gravimetrically by precipitation with nitrato-pentammine-cobaltinitrate and sodium molybdate in sulfuric acid solution. Weight of precipitate times 0.01515 gives weight of phosphorus. Potassium does not interfere but ammonium must be removed, as must nitric and hydrochloric acids.—*Selma Gottlieb.*

Microdetermination of Fluorine. Wallace D. Armstrong. Ind. Eng. Chem., Anal. Ed., 8, 5, 384–7 (1936). Willard and Winter method is modified for microquantities of fluorine. Amount of perchloric acid evolved is reduced by adding sodium perchlorate before distillation. Fluoride is titrated in aqueous instead of alcoholic solution to produce exact equivalence between thorium nitrate solution and fluoride. Chloride, when present in interfering amounts, is removed with silver perchlorate.—*Selma Gottlieb.*

Turbidimeter for Water Ranging from 0 to 15 P.P.M. A. V. Graf. W. Wks. Eng. 89: 982, 1936. Author gives complete working drawings and describes in detail an apparatus for determining low turbidities in water supply. The glass tubes are 100 cc. short form Nessler tubes, free from scratches or other imperfections. Attention is called to the fact that glass-ware should be scrupu-

lously clean and fresh standards should be made daily from stock suspensions. Detailed working drawings accompany the descriptive article.—*Lewis V. Carpenter.*

Determination of Lead in Potable Water. S. L. TOMPSETT. Analyst, 61: 726, 591, 1936. Volume of water containing 0.05–0.10 mg. lead evaporated to small bulk and is heated with 1 c.c. each of concentrated sulphuric and perchloric acids until organic matter destroyed. To cooled residue (free from perchloric acid) is added 10 c.cs. water, 1 c.c. glacial acetic, 5 c.cs. 20 per cent sodium citrate, 5 c.cs. strong ammonia, 6 drops of 5 percent sulphurous acid, 5 c.cs. 10 percent potassium cyanide, 10 c.cs. carbon tetrachloride and 0.5 c.c. of 0.1 percent diphenylthiocarbazone in carbon tetrachloride. Carbon tetrachloride extract separated, washed with three or four 5 c.c. portions of potassium cyanide and compared colorimetrically with standards similarly prepared. When iron content is high, preliminary separation of lead with sodium diethyldithiocarbamate is necessary.—*W. G. Carey.*

CORROSION

Corrosion of Steel by Oil Well Waste Waters. W. F. ROGERS AND W. A. SHELLSHEAR. Ind. Eng. Chem., 29, 2, 160–6 (1937). Oil well waste waters containing up to 80 grams of soluble salts per liter are noncorrosive to cold-rolled sheet steel in pH range 6.4 to 8.0 if oxygen is absent. Hydrogen sulfide-bearing oil well waste waters are noncorrosive at pH 6.6 to 6.8, but corrosiveness is greatly increased at pH 5.4. Waters carrying as much as 2.6 c.c. of oxygen per liter are noncorrosive in presence of more than 30% of oil.—*Selma Gottlieb.*

Symposium on New Metals and Alloys Applicable to the Chemical Industry. Evolution of New Metals. B. D. SAKLATWALLA. Ind. Eng. Chem., 28, 12, 1366–73 (1936). Last 25 years have seen great advances in metallurgy, though progress has been retarded by limitations of methods of metal testing (e.g., corrosion studies). In steel metallurgy most recent important development is low-alloy, high-tensile strength, corrosion-resistant steel, with nearly twice yield strength of ordinary carbon steel of same carbon content. High-chromium steels (stainless steels), non-ferrous metals (e.g., aluminum, nickel, silver, platinum) and composite metals have all contributed to metallurgical progress. **Steels Resistant to Scaling and Corrosion.** FLORENCE FENWICK AND JOHN JOHNSTON. Ibid., 1374–9. High-strength steels in many instances can be used to advantage only if more resistant to corrosion than ordinary ferrous materials, especially where structure is lightened. Corrosion resistance depends on tendency of metal to react with environment, rate of reaction under conditions of exposure, solubility, mechanical characteristics, chemical reactivity, and perviousness to diffusion of film formed. Film characteristics of given metal cannot be predicted at present time but must be determined experimentally. New chromium-copper-silicon-phosphorus steel called Cor-Ten is more resistant to corrosion than copper steel when exposed to air, fresh or salt water or certain mine waters. In recent work, development of optimum

properties of steel by methods of manufacture is emphasized as well as chemical composition. **Discussion of New Ferrous Alloys for the Oil Industry.** L. W. VOLLMER AND BLAINE WESTCOTT. Ibid., 1379–80. **Chromium and Its Alloys.** W. J. PRIESTLEY. Ibid., 1381–5. Commercial grades of corrosion-resisting and stainless steel contain 1.00 to 35.00% of chromium, types being available for various uses. Variety of elements is used for modifying properties of straight chromium steels. Properties and uses of various types are discussed: mild alloy steels containing less than 3.50% of chromium; the 3.50 to 9.00% chromium steels, developed as compromise in quality and cost between stainless steels and plain carbon steel; steels containing 10 to 16% of chromium, stainless if hardened and polished; steels containing 16 to 20% of chromium, having excellent corrosion and oxidation resistance without special heat treatment; steels with over 20% chromium, offering good resistance to oxidation up to 2000°F.; austenitic steels, containing 17 to 20% of chromium and 7 to 10% of nickel. Last named are best known and most widely used stainless and corrosion resistant steels because of ease of fabrication and good physical properties at high and low temperatures. Special higher chromium-nickel steels are also made. **Nickel and Corrosion-Resisting Nickel Alloys.** ROBERT J. MCKAY. Ibid., 1391–7. Properties of commercially pure nickel, monel metal and its modification, chromium-nickel and copper nickel alloys, stainless steels, austenitic cast irons, special alloy irons, nickel clad steel and nickel electroplate are discussed. Making of corrosion-resisting joints depends on properties of alloy; most nickel alloys can be welded successfully, yielding welds very close to original alloy in composition and corrosion resistance. Brazing alloys and silver or tin-lead solders, or riveted or screwed joints may be used, depending on alloy and conditions of use. **Wrought Copper Base Alloys.** D. K. CRAMPTON. Ibid., 1937–1400. Copper tubes are highly suited to most water conditions, being low in cost, easy to install, neat in appearance, light in weight, excellent in corrosion resistance, and high in strength and resistance to damage from use or abuse. Various commercial solders on copper tubing yielded joints giving excellent service when saline water was pumped through line with air-lift pump for two years at 60°C. Properties and uses of tinned copper, red brass, cupronickel, silicon bronzes and newer alloys are discussed. Red brass containing about 85% copper and 15% zinc cannot be dezincified under any conditions found in domestic water supplies, though pure copper is somewhat subject to pitting in many waters; red brass is distinctly superior in resisting this attack. Cupronickels, containing 20 to 30% of nickel, up to 5% of zinc and balance mainly copper, are highly successful as condenser tubes, being resistant to impingement, water line and deposit types of attack, as well as to dezincification and corrosion cracking. Silicon bronzes are highly resistant to all waters and are recommended for welded water tanks. Aluminum brasses containing up to about 2% aluminum are relatively new development, and have extraordinary resistance to impingement in condenser tubes. Addition of tin aids immunity to dezincification under practically all conditions. For oil refinery use, composite condenser and heat-exchanger tubes have been developed with one side resistant to water and the other to oil. **Aluminum and Its Alloys.** WM. L. FINK. Ibid., 1402–6. Advantages of aluminum include low density, high

thermal and electrical conductivity, low modulus of elasticity, high plasticity, high thermal reflectivity, and absence of color and toxicity in corrosion products. Corrosiveness under certain conditions is a disadvantage. Certain alloys of aluminum (e.g., with manganese, magnesium or silicon) and Alclad materials (aluminum alloy clad with another and more anodic aluminum alloy) have advantages over commercial aluminum for certain purposes. **New Metals and Alloys from Lead, Tin, Zinc and Antimony.** GEORGE O. HIERS. Ibid., 1406–8. Tellurium lead (ordinary lead containing 0.05% tellurium) is recent and spectacular development, and is superior to lead in both physical and chemical properties. It has higher endurance than lead, and has capacity for work-hardening. Alloys containing tin, lead, cadmium, calcium or silver, or various combinations of them, have advantages for certain purposes. Hard lead contains 6 to 28% antimony. Tin-base babbitt metal for bearings can be improved by addition of 1% cadmium. Improvements in galvanized iron include heavier zinc coating, and electrodeposition of zinc coating followed by mechanical treatment. Modern zinc base die-casting alloys have overcome difficulties with older type. **Discussion.** L. S. DEITZ. Ibid., 1409–10. Metal coatings are applied by spraying molten metal on desired surface. Zinc is most widely used now but lead, tin, aluminum, monel metal, nickel and steel have their uses. Use of lead alloys containing up to 12% antimony for storage battery grids makes possible casting of thinner grids (as thin as 0.055 to 0.060 in.). New lead alloys containing 0.05% to 0.10% of calcium show possibility of improving electrical properties of batteries as well as physical properties of grids. Nearly all common construction materials are subject to intercrystalline penetration by solder to some extent. Nickel, monel metal, cupronickel and low carbon steels are only slightly affected but higher carbon steels and nickel-chromium steels are more susceptible. **Some Aspects of Steel Chemistry.** JOHN JOHNSTON. Ibid., 1427–23. Discussion of steel-making processes, nature of steel, and influence of heat treatment and alloying metals on nature of final product. **Beryllium-Copper Alloys.** HORACE F. SILLIMAN. Ibid., 1424–8. Beryllium-copper alloys containing 2.0 to 2.25% of beryllium, with or without addition of certain other metals, have been used in last four years for springs and articles having spring parts, non-sparking hand tools, precision bearings, woven wire cloth, etc. Outstanding characteristic of these alloys is resistance to wear and fatigue. They can be worked either hot or cold. Properties can be modified by annealing at 800°C. and heat treatment at 275°. Because of film-forming nature of beryllium oxide, these alloys must be arc or resistance welded, and surfaces must be mechanically cleaned before soldering.—*Selma Gottlieb.*

The Resistance of Galvanized Iron to Corrosion of Domestic Water Supplies. S. C. BRITTON. Chem. and Ind., 55: 4, 19T–22T, 1936. Describes experiments made by British Non-Ferrous Metals Research Association and draws following conclusions. In waters with pH of 7.5–9.5 containing calcium bicarbonate and low sulphates, chlorides and nitrate the attack on zinc is soon stifled but on iron may continue evenly over metal surface. Waters low in bicarbonates or containing appreciable sulphate, chloride or nitrate the zinc is liable to pitting, on iron corrosion spread out. With zinc an insoluble car-

bonate layer forms on attacked area and limits their size, with iron insoluble product becomes removed. Zinc, when clean, affords electrochemical protection to iron, but when coated with resistant layer of corrosion products distance at which it will give protection becomes much decreased. Zinc protects alloy layer of galvanized coating where laid bare but alloy layer will not electrochemically protect bared iron. Calcium carbonate deposited on alloy or iron in course of electrochemical protection is itself protective and ultimate success of electrochemical protection of any exposed area depends on building up of protective effect of this chalk layer at greater rate than protection lost by dissolution of adjacent zinc. Thickness of zinc layer, calcium bicarbonate content, pH value, and conductivity of water are deciding factors. —*W. G. Carey.*

Corrosion of Metals by Water and Carbon Dioxide under Pressure. F. H. Rhodes and John M. Clark, Jr. Ind. Eng. Chem., 28, 9, 1078–9 (1936). In corrosion of metals by water and carbon dioxide under pressure, initial rate may be much higher than final rate, especially with softer metals. For carbon steel, corrosion rate increases rapidly with pressure up to 300 lbs. of carbon dioxide pressure per sq. in., but little more up to 450 lbs. Of nonferrous metals studied, only zinc was pitted. Most nonferrous metals were corroded less than steel, but stainless steel was practically unattacked.—*Selma Gottlieb.*